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(54) **SYSTEM AND METHOD OF MONITORING VIDEO DATA PACKET DELIVERY**

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H04N 21/239	(2011.01)
H04N 21/24	(2011.01)
H04N 21/258	(2011.01)
H04N 21/643	(2011.01)
H04N 7/173	(2011.01)
G06F 15/16	(2006.01)

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CPC ***H04N 7/17318*** (2013.01); ***H04L 12/1868*** (2013.01); ***H04N 21/2393*** (2013.01); ***H04N 21/2404*** (2013.01); ***H04N 21/258*** (2013.01); ***H04N 21/64322*** (2013.01)

(58) **Field of Classification Search**

USPC 709/224; 714/25, 748, 18, 749, 47.1, 714/47.2; 725/112, 113, 107, 118, 119; 370/242; 348/192

See application file for complete search history.

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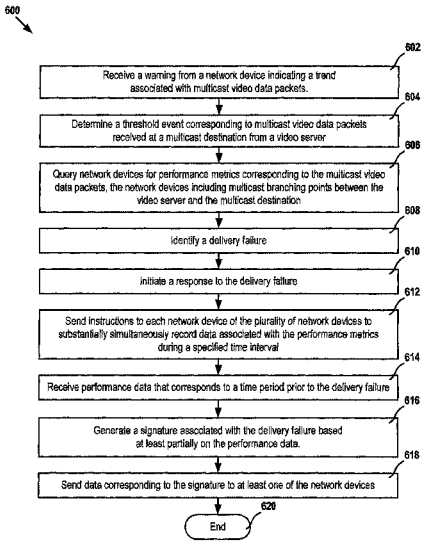
(57) **ABSTRACT**

Systems and methods of monitoring packet delivery are disclosed. In an embodiment, a method is disclosed that includes querying multiple network devices for performance metrics corresponding to video data packets sent from a video server. The network devices may include multicast branching points between the video server and the destination. A delivery failure may be identified based on the performance metrics, and a response to the delivery failure may be initiated.

28 Claims, 8 Drawing Sheets



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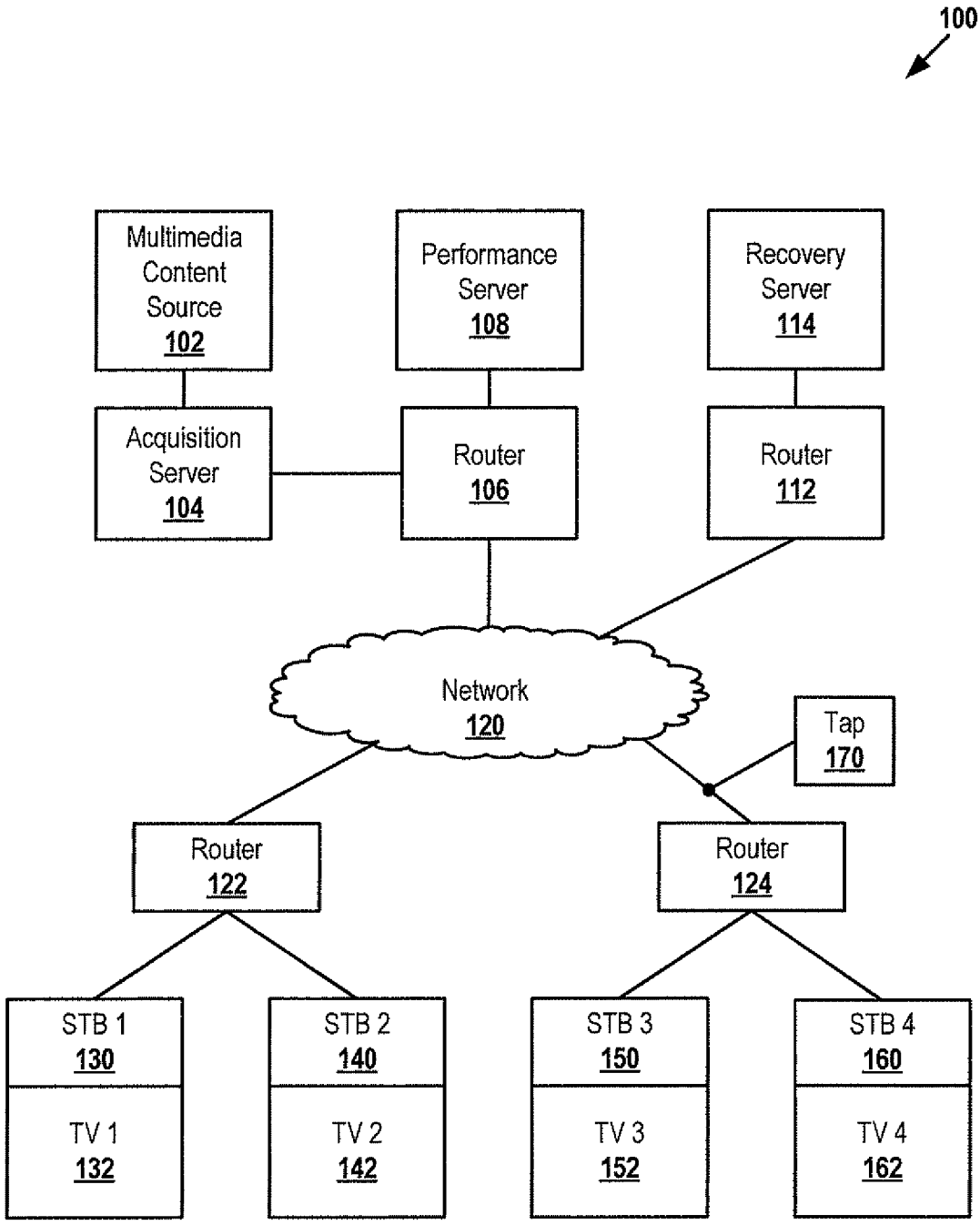
100
Multimedia Content Source 102
Performance Server 108
Recovery Server 114
Acquisition Server 104
Router 106
Router 112
Network 120
Tap 170
Router 122
Router 124
STB 1 130
TV 1 132
STB 2 140
TV 2 142
STB 3 150
TV 3 152
STB 4 160
TV 4 162

FIG. 1

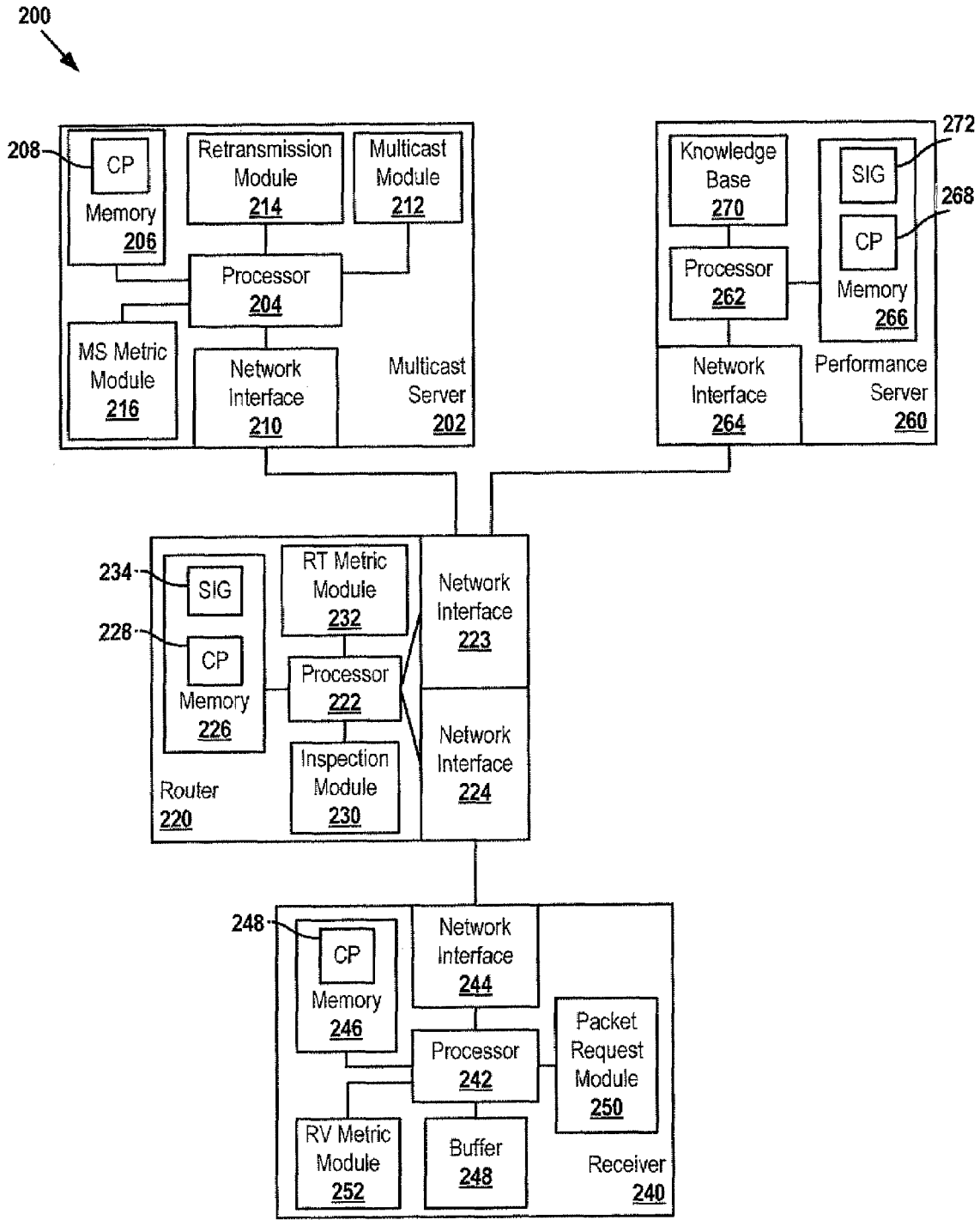
200
208
CP
Memory
206
Retransmission Module
214
Multicast Module
212
Processor
204
MS Metric Module
216
Network Interface
210
Multicast Server
202
272
Knowledge Base
270
SIG
268
CP
Processor
262
Memory
266
Network Interface
264
Performance Server
260
234
SIG
228
CP
Memory
226
RT Metric Module
232
Processor
222
Inspection Module
230
Router
220
Network Interface
223
Network Interface
224
248
CP
Memory
246
Network Interface
244
Processor
242
Packet Request Module
250
RV Metric Module
252
Buffer
248
Receiver
240

FIG. 2

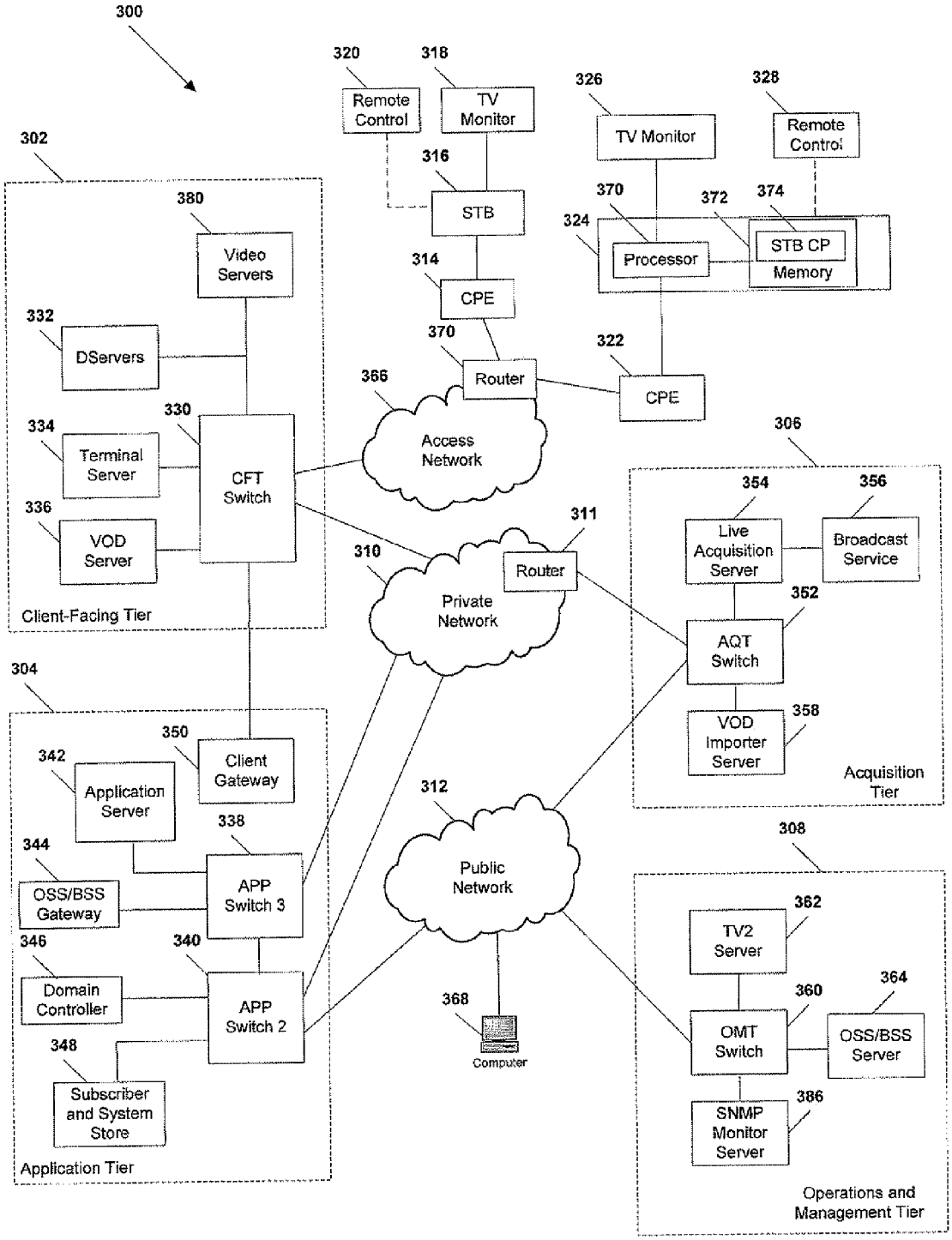
300
320
Remote Control
318
TV Monitor
326
TV Monitor
328
Remote Control
302
316
STB
380
Video Servers
370
372
374
324
Processor
STB CP
Memory
314
CPE
332
DServers
370
Router
322
CPE
366
Access Network
330
334
Terminal Server
CFT Switch
306
336
VOD Server
354
356
Live Acquisition Server
Broadcast Service
311
310
Router
Private Network
352
AQT Switch
Client-Facing Tier
304
358
VOD Importer Server
Acquisition Tier
350
Client Gateway
342
Application Server
312
338
344
Public Network
308
APP Switch 3
OSS/BSS Gateway
362
TV2 Server
346
340
360
364
Domain Controller
APP Switch 2
368
OMT Switch
OSS/BSS Server
Computer
348
386
Subscriber and System Store
SNMP Monitor Server
Application Tier
Operations and Management Tier

FIG. 3

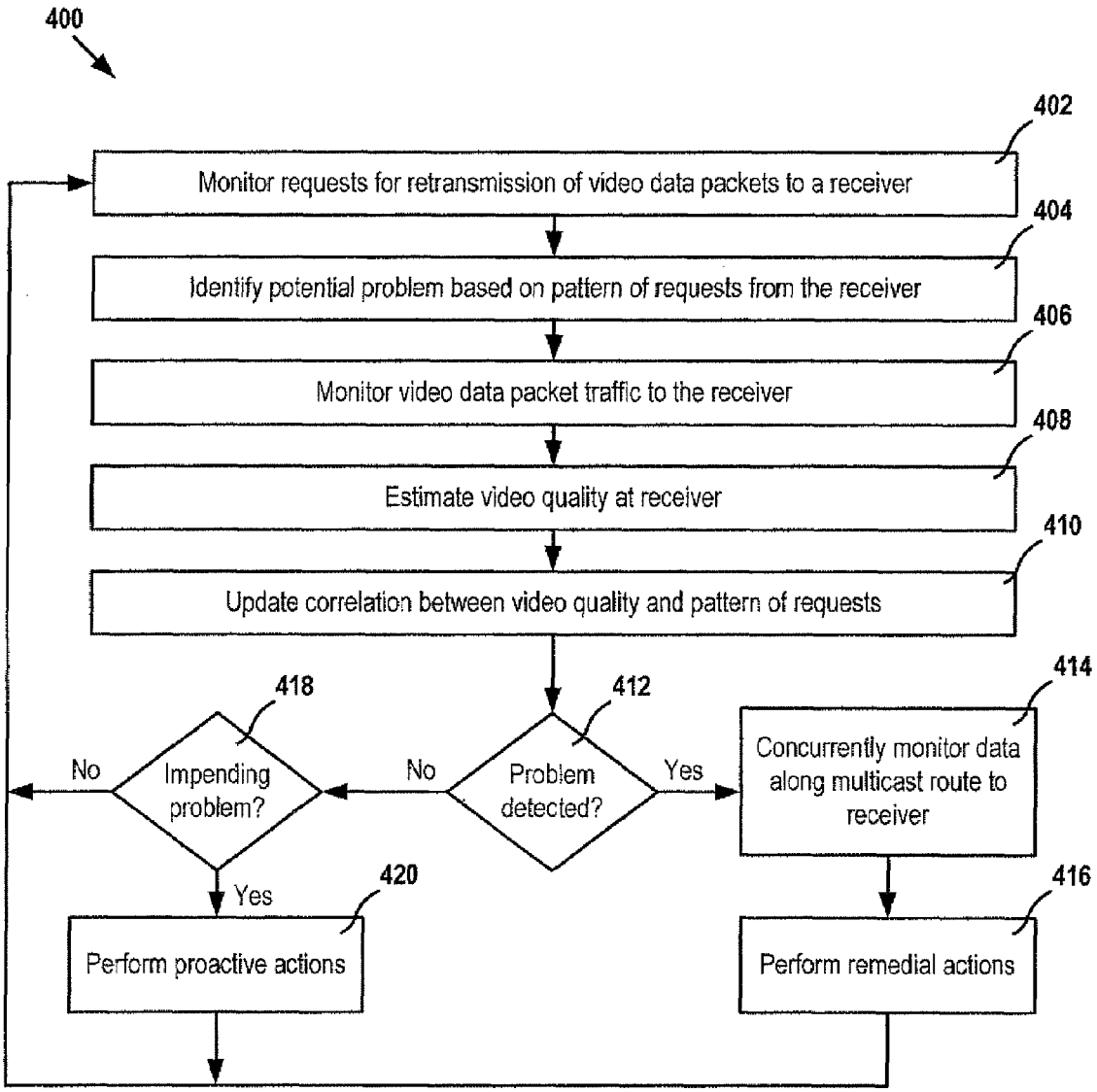
400
402
Monitor requests for retransmission of video data packets to a receiver
404
Identify potential problem based on pattern of requests from the receiver
406
Monitor video data packet traffic to the receiver
408
Estimate video quality at receiver
410
Update correlation between video quality and pattern of requests
412
Problem detected?
Yes
414
Concurrently monitor data along multicast route to receiver
416
Perform remedial actions
No
418
Impending problem?
Yes
420
Perform proactive actions
No

FIG. 4

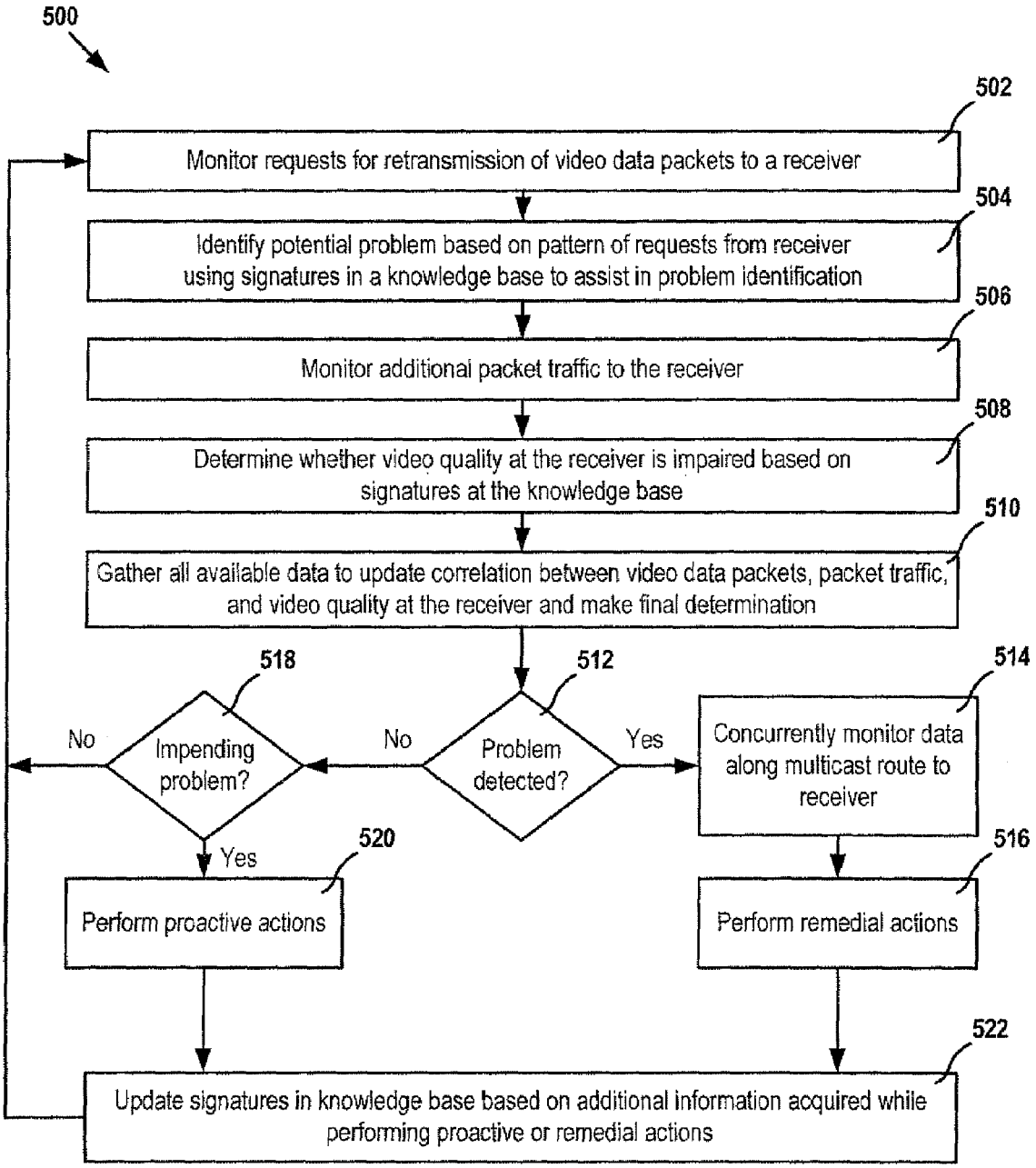
500
502
Monitor requests for retransmission of video data packets to a receiver
504
Identify potential problem based on pattern of requests from receiver using signatures in a knowledge base to assist in problem identification
506
Monitor additional packet traffic to the receiver
508
Determine whether video quality at the receiver is impaired based on signatures at the knowledge base
510
Gather all available data to update correlation between video data packets, packet traffic, and video quality at the receiver and make final determination
518
Impending problem?
No
512
Problem detected?
No
Yes
514
Concurrently monitor data along multicast route to receiver
Yes
520
Perform proactive actions
516
Perform remedial actions
522
Update signatures in knowledge base based on additional information acquired while performing proactive or remedial actions

FIG. 5

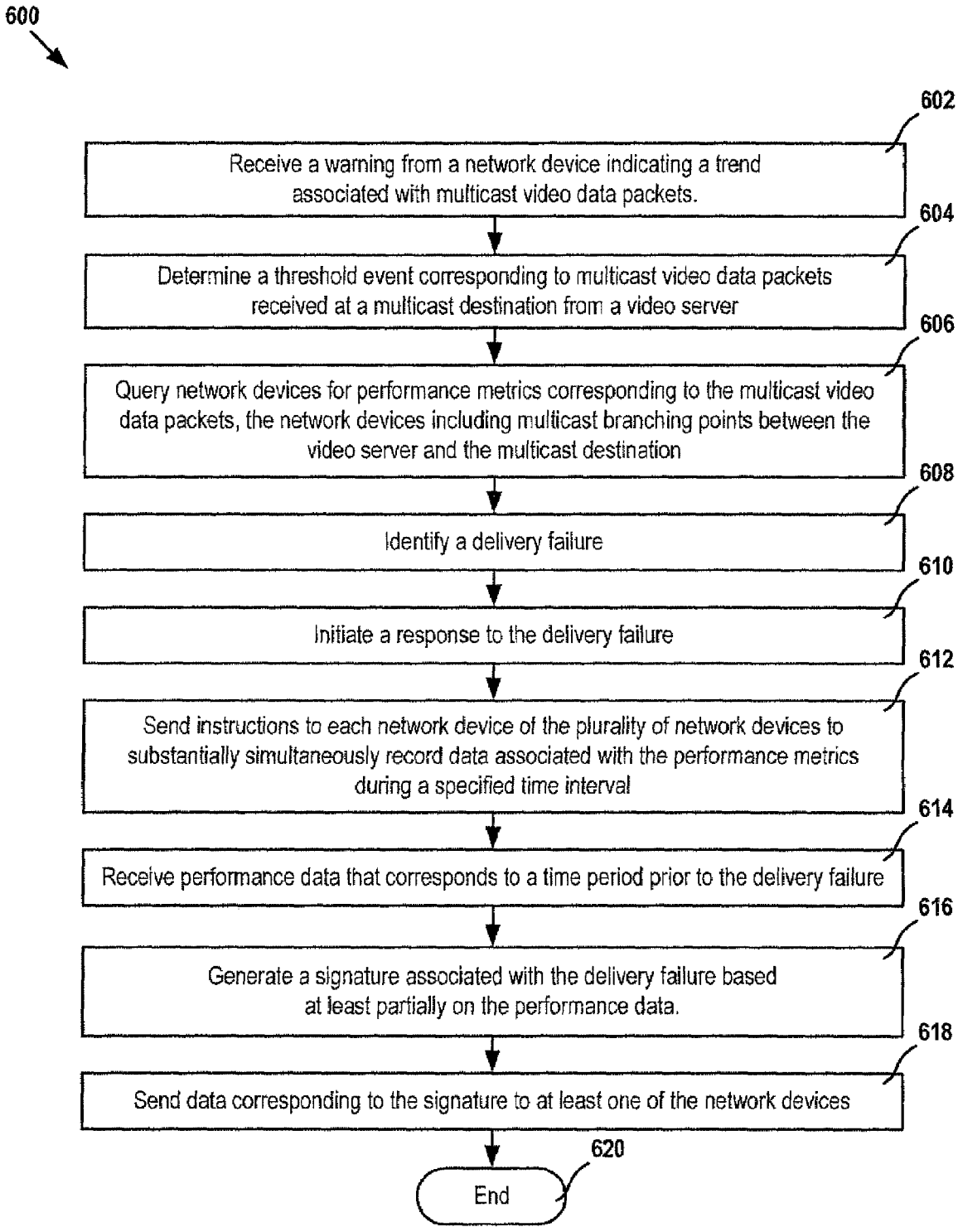
600
602
Receive a warning from a network device indicating a trend associated with multicast video data packets.
604
Determine a threshold event corresponding to multicast video data packets received at a multicast destination from a video server
606
Query network devices for performance metrics corresponding to the multicast video data packets, the network devices including multicast branching points between the video server and the multicast destination
608
Identify a delivery failure
610
Initiate a response to the delivery failure
612
Send instructions to each network device of the plurality of network devices to substantially simultaneously record data associated with the performance metrics during a specified time interval
614
Receive performance data that corresponds to a time period prior to the delivery failure
616
Generate a signature associated with the delivery failure based at least partially on the performance data.
618
Send data corresponding to the signature to at least one of the network devices
620
End

FIG. 6

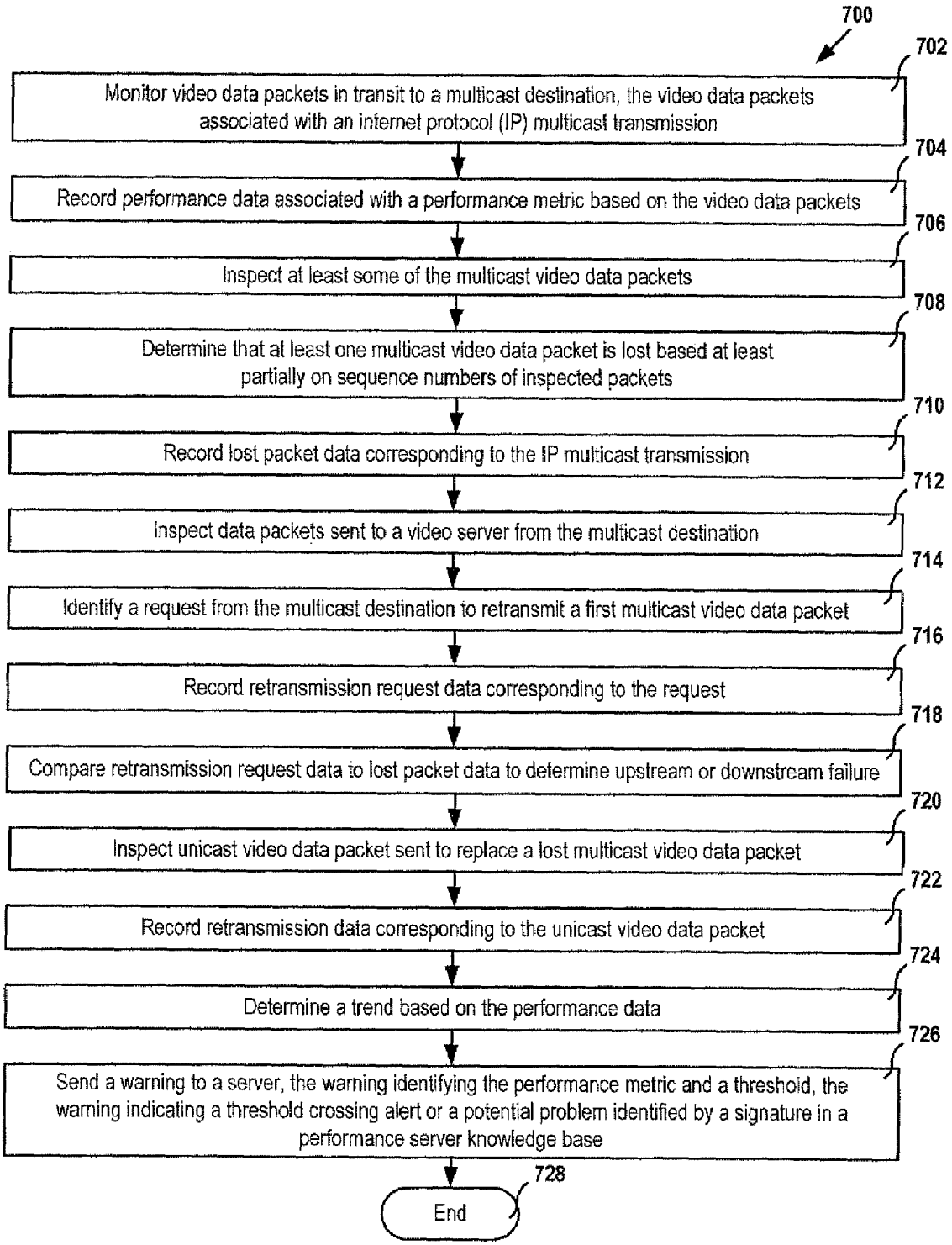
700
702
Monitor video data packets in transit to a multicast destination, the video data packets associated with an internet protocol (IP) multicast transmission
704
Record performance data associated with a performance metric based on the video data packets
706
Inspect at least some of the multicast video data packets
708
Determine that at least one multicast video data packet is lost based at least partially on sequence numbers of inspected packets
710
Record lost packet data corresponding to the IP multicast transmission
712
Inspect data packets sent to a video server from the multicast destination
714
Identify a request from the multicast destination to retransmit a first multicast video data packet
716
Record retransmission request data corresponding to the request
718
Compare retransmission request data to lost packet data to determine upstream or downstream failure
720
Inspect unicast video data packet sent to replace a lost multicast video data packet
722
Record retransmission data corresponding to the unicast video data packet
724
Determine a trend based on the performance data
726
Send a warning to a server, the warning identifying the performance metric and a threshold, the warning indicating a threshold crossing alert or a potential problem identified by a signature in a performance server knowledge base
728
End

FIG. 7

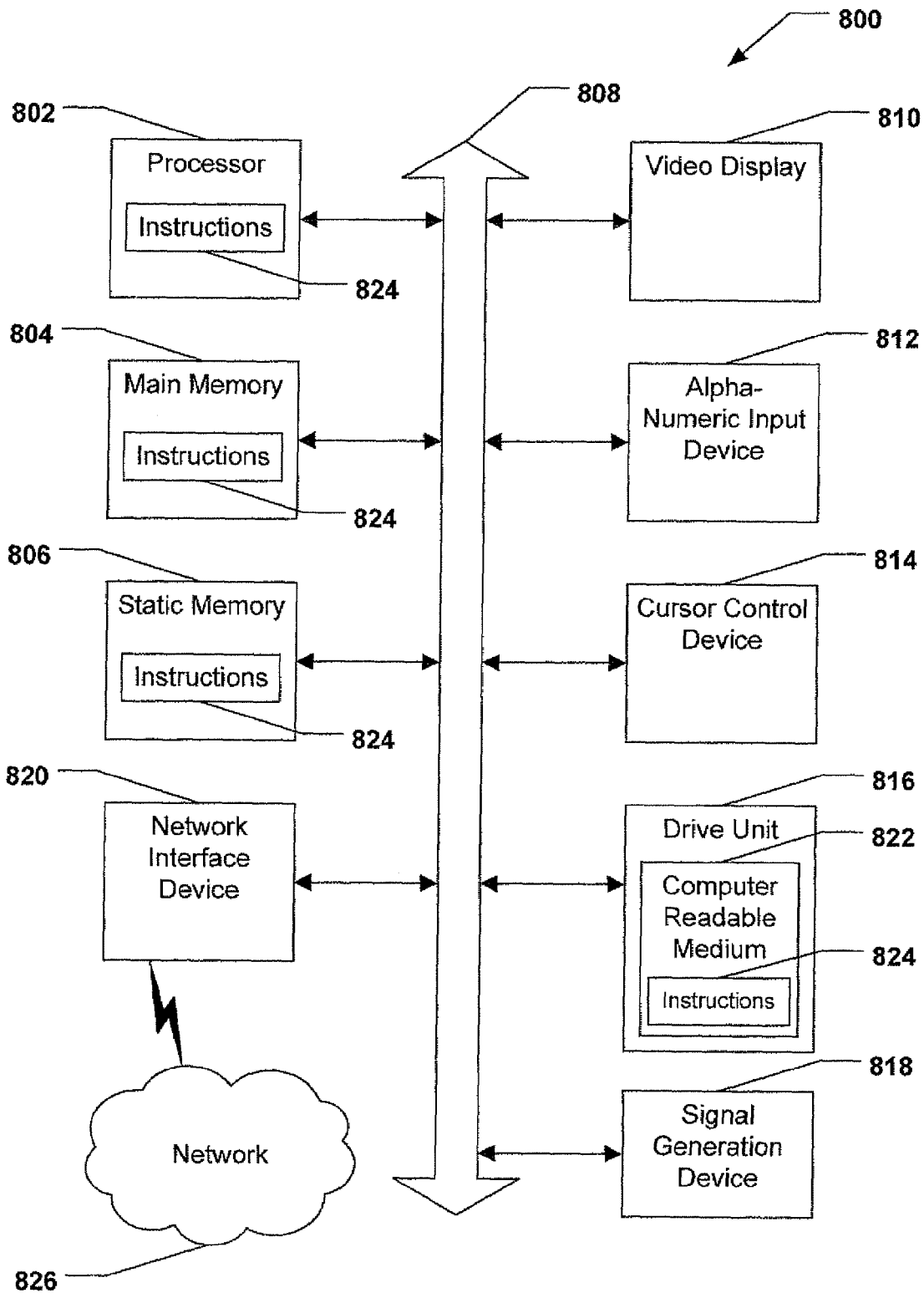
800
808
802
Processor
Instructions
824
810
Video Display
804
Main Memory
Instructions
824
812
Alpha-Numeric Input Device
806
Static Memory
Instructions
824
814
Cursor Control Device
820
Network Interface Device
816
Drive Unit
822
Computer Readable Medium
Instructions
824
818
Signal Generation Device
Network
826

FIG. 8

SYSTEM AND METHOD OF MONITORING VIDEO DATA PACKET DELIVERY

FIELD OF THE DISCLOSURE

The present disclosure is generally related to monitoring video data packet delivery.

BACKGROUND

Multimedia content can be delivered from a source to a receiver via a stream of video data packets. Image quality may be affected by the loss of one or more packets of the stream of video data packets. Packet losses can be caused by network congestion, packet errors, network device failures, other causes, or any combination thereof. Hence, there is a need for an improved system and method of monitoring video data packet delivery.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a particular embodiment of a system to monitor video data packet delivery;

FIG. **2** is a block diagram of a second particular embodiment of a system to monitor video data packet delivery;

FIG. **3** is a block diagram of an Internet Protocol Television (IPTV) system;

FIG. **4** is a flow chart of a particular embodiment of a method of monitoring video data packet delivery;

FIG. **5** is a flow chart of a second particular embodiment of a method of monitoring video data packet delivery;

FIG. **6** is a flow chart of a third particular embodiment of a method of monitoring video data packet delivery;

FIG. **7** is a flow chart of a fourth particular embodiment of a method of monitoring video data packet delivery; and

FIG. **8** is a block diagram of an illustrative embodiment of a general computer system.

DETAILED DESCRIPTION

In a particular embodiment, a system is disclosed that includes a processor and a network interface accessible to the processor. The system also includes a memory accessible to the processor, the memory having instructions to cause the processor to execute a method. The method includes determining that a number of multicast video data packets not received at a multicast destination exceeds a threshold, the multicast video data packets sent from a video server to the multicast destination. The method includes querying a plurality of network devices for performance metrics corresponding to the multicast video data packets. The method includes identifying a delivery failure. The method further includes initiating a response to the delivery failure.

In another embodiment, a system is disclosed that includes a first network interface to communicate with a first network and a second network interface to communicate with a second network. The system also includes a processor coupled to the first network interface and the second network interface. The system father includes a memory accessible to the processor, the memory having instructions to cause the processor to execute a method. The method includes receiving video data packets at the first network interface, the video data packets sent to a multicast destination coupled to the second network. The method also includes recording performance data associated with the video data packets. The method includes determining a trend based on the performance data. The method further includes sending a warning to a server, the warning indicating that the performance metric is predicted to exceed a threshold.

In another embodiment, a method of monitoring video data packet delivery is disclosed. The method includes querying a plurality of network devices for performance metrics corresponding to multicast video data packets, the multicast video data packets sent from a video server of an internet protocol television system to a multicast destination. The plurality of network devices includes multicast branching points between the video server and the multicast destination. The method includes identifying a delivery failure based on the performance metrics. The method also includes initiating a response to the delivery failure.

In another embodiment, a second method of monitoring video data packet delivery is disclosed. The method includes monitoring video data packets in transit to a multicast destination, the video data packets associated with an internet protocol (IP) multicast transmission. The method includes recording performance data associated with a performance metric based on the video data packets. The method includes determining a trend based on the performance data. The method further includes sending a warning to a server, the warning identifying the performance metric and a threshold.

In another embodiment, a computer readable medium is disclosed. The computer readable medium has computer readable instructions to cause a processor to execute a method. The method includes recording a first number of lost video packets of a multicast transmission that are not received at a multicast destination from a first server. The method includes recording a second number of lost retransmission packets that are requested from the first server but not received at the multicast destination. The method also includes sending a message to a second server when at least one of the first number and the second number exceeds a threshold.

Referring to FIG. **1**, a particular embodiment of a system to monitor video data packet delivery is depicted and generally designated **100**. The system **100** includes a multimedia content source **102** that can communicate with a video content acquisition server **104**. The acquisition server **104** is adapted to communicate with a performance server **108** via a first representative router **106**. The acquisition server **104** can communicate with a video packet loss recovery server **114** via the first representative router **106**, a network **120** and a second representative router **112**. In a particular illustrative embodiment, the network **120** may be a public internet protocol (IP) network, a private IP network, or any combination thereof. Further, the recovery server **114** can communicate with a plurality of set-top boxes via the second router **112**, the network **120**, and routers **122** and **124**. For instance, the recovery server **114** can communicate with a first set-top box device (STB) **130** and a second STB **140**, via the third representative router **122**, and can communicate with a third STB **150** and a fourth STB **160** via the fourth representative router **124**. Each STB **130**, **140**, **150**, and **160** may be coupled to a display device such as a first television **132**, a second television **142**, a third television **152**, and a fourth television **162**, respectively. A tap **170** to monitor network communications without functioning as a switch or a router may be coupled to a communication path between the network **120** and the fourth router **124**.

In a particular illustrative embodiment, the multimedia content source **102** can provide multimedia content to the acquisition server **104** for distribution. As illustrative, non-limiting examples, the multimedia content source **102** can

include a television content provider, other sources of multimedia content, or any combination thereof.

In a particular illustrative embodiment, the acquisition server **104** may be adapted to encode the multimedia content for transmission to the recovery server **114** via the first router **106**, the network **120**, and the second router **112**. The acquisition server **104** may be adapted to encapsulate the multimedia content into a sequence of media content data packets for delivery to the recovery server **114**. In a particular embodiment, the media content packets may be encoded as Internet Protocol (IP) packets. In a particular embodiment, the acquisition server **104** may be adapted to transmit the multimedia content via one or more streams of media content packets to multiple multicast destinations, such as multiple recovery servers **114**, to one or more of the STBs **130**, **140**, **150**, and **160**, to other end-user or network resources (not shown) that are capable of receiving multicast video data packets, or any combination thereof. In an illustrative embodiment, the acquisition server **104** may be adapted to transmit video data via IP multicast using Real-time Transport Protocol (RTP).

In a particular embodiment, the acquisition server **104** may be adapted to receive requests to resend packets and may be adapted to resend the requested packets. In a particular embodiment, the acquisition server **104** may be adapted to track metrics associated with one or more multicast receivers based on the received requests to resend the packets. Such multicast receivers can include the recovery server **114**, one or more of the STBs **130**, **140**, **150**, and **160**, other multicast receivers (not shown), or any combination thereof. In a particular non-limiting example, the acquisition server **104** may be adapted to record data corresponding to lost packets, such as a lost packet identifier, a number or identification of multicast receivers that did not receive an identified packet, or a number or identification of multicast receivers that did not receive a retransmitted video data packet.

In a particular embodiment, the acquisition server **104** may be adapted to determine when one or more tracked metrics meets or exceeds one or more thresholds and to notify the performance server **108** based on the determination. In an illustrative embodiment, a threshold may correspond to a number of lost packets to a single multicast destination, a total number of lost packets for all multicast destinations, a sum of lost multicast packets and failed retransmission packets, or any combination thereof. In an illustrative embodiment, the threshold may be related to a specified time interval, such as a number of lost packets per hour. In another illustrative embodiment, the threshold may be based on a relative amount, such as a ratio of lost packets to total transmitted packets.

In a particular illustrative embodiment, the acquisition server **104** may be adapted to determine a trend in the tracked metrics and to generate an alert or message to the performance server **108** when a threshold is predicted to be exceeded based on the trend. In a particular embodiment, the acquisition server **104** may be adapted to predict an amount of time before one or more thresholds is reached. The A-server may be adapted to send a message to the performance server **108** when the predicted amount of time is less than a predetermined amount of time.

In a particular embodiment, the recovery server **114** may be adapted to receive multimedia content from the acquisition server **104** and to store, format, encode, replicate, or otherwise manipulate or prepare the multimedia content for communication to the set-top box devices **130**, **140**, **150**, and **160**. In a particular embodiment, the recovery server **114** may be adapted to detect when one or more packets of a multicast transmission are not received at the recovery server **114**. In a particular embodiment, each transmitted multicast packet may be associated with a multicast packet sequence number. The recovery server **114** may be adapted to identify missing packets by sequence number and to transmit a request that identifies missing sequence numbers to the acquisition server **104**.

In a particular embodiment, the recovery server **114** may be adapted to track data associated with one or more performance metrics and to notify the performance server **108** when one or more thresholds has been met or exceeded. In a particular embodiment, the recovery server **114** may be adapted to track data associated with lost multicast packets not received from the acquisition server **104**. The recovery server **114** may be adapted to track failed redelivery requests for lost multicast packets from the acquisition server **104**. In a particular embodiment, the recovery server **114** may be adapted to track multicast packet loss to one or more of the STBs **130**, **140**, **150**, and **160**. In a particular embodiment, the recovery server **114** may be adapted to track packet retransmission failures to one or more of the STBs **130**, **140**, **150**, and **160**.

In a particular embodiment, the recovery server **114** may be adapted to send a message to the performance server **108** when one or more one or more performance metrics meet or exceed a respective threshold. In a particular embodiment, the recovery server **114** may be adapted to predict a future threshold crossing of one or more of the performance metrics by extrapolating a trend in the performance data. In a particular embodiment, the recovery server **114** may be adapted to send a warning to the performance server **108** identifying the predicted threshold crossing.

In a particular embodiment the set-top box devices **130**, **140**, **150**, and **160** may be adapted to detect when one or more packets of the multimedia content are not received. In an illustrative embodiment, each STB **130**, **140**, **150**, and **160** may be adapted to buffer received packets by packet sequence number and to transmit a request identifying missing packet sequence numbers to the recovery server **114**. In a particular embodiment, one or more of the STBs **130**, **140**, **150** and **160** may be adapted to track performance data such as a number of lost multicast packets, a number of failed packet redelivery requests, or any combination thereof. In a particular embodiment, the STBs **130**, **140**, **150**, and **160** may be adapted to detect when performance metrics indicate a trend that exceeds or will exceed a threshold and to send a message identifying the predicted or actual threshold crossing to the performance server **108**.

In a particular embodiment, one or more of the representative routers **106**, **112**, **122**, and **124** may be adapted to monitor multicast traffic and to record performance data associated with one or more multicast transmissions. In a particular embodiment, the routers **106**, **112**, **122**, and **124** may be adapted to record performance data in response to receiving an instruction from the performance server **108**. The routers **106**, **112**, **122**, and **124** may be adapted to send requested information to the performance server **108** automatically or upon receiving a request.

In a particular embodiment the routers **106**, **112**, **122**, and **124** may be adapted to receive and to access signature data associated with one or more delivery failures. The signature data may include network performance data that is characteristic of an impending delivery failure. The routers **106**, **112**, **122**, and **124** may be adapted to compare performance data to the signature data to predict a potential delivery failure or to diagnose at least a portion of an actual delivery failure. The routers **106**, **112**, **122**, and **124** may be adapted to send a message to the performance server **108** identifying a predicted or diagnosed delivery failure.

In a particular embodiment, the routers **106**, **112**, **122**, and **124** may be adapted to perform deep packet inspection of multicast traffic, unicast traffic, or any combination thereof. In a particular embodiment, the routers **106**, **112**, **122**, and **124** may be configured to record data from the deep packet inspection, such as identifying multicast packets that are lost by detecting missing multicast sequence identifiers, or detecting multicast packets not received at one or more downstream multicast destinations by inspecting packet redelivery requests from the multicast destinations.

In a particular embodiment the tap **170** may include a device that is adapted to perform packet traffic monitoring, deep packet inspection, and other functions in a manner substantially similar to the routers **106**, **112**, **122**, and **124**, but may not include a switch or router. In an illustrative embodiment, the router **124** may not be configured to monitor video data packet delivery, and instead the tap **170** may perform the monitoring for the multicast branch from the access network **120** to the router **124**.

In a particular embodiment, the performance server **108** may be adapted to monitor video data packet delivery. In a particular embodiment, the performance server **108** may be adapted to receive messages indicating delivery failures, such as from the recovery server **114**, one or more of the STBs **130**, **140**, **150**, and **160**, one or more other devices coupled to the access network **120** to receive video data (not shown), or any combination thereof. In a particular embodiment, the performance server **108** may be adapted to identify one or more delivery failures and the initiate a response. In a particular embodiment, the response may include sending a notice to one or more administrators of the system **100**, automatically redirecting network traffic, sending instructions to network devices to provide performance data for diagnostics, other responses appropriate to the delivery failure, or any combination thereof.

During operation, data associated with video data packet traffic to the STBs **130**, **140**, **150** and **160** may be tracked and used for determining trends and predicting future delivery problems. Video quality at a receiver, such as the STBs **130**, **140**, **150** and **160**, may be estimated by tracking video data packet traffic at a location between a video content source and the receiver. Generally, estimates of video quality at a receiver become more accurate as the video packet traffic flow is monitored nearer to the receiver. However, continual monitoring of video data packet traffic at each receiver can be prohibitively expensive and resource-intensive. Therefore, video quality at the receivers may be monitored via requests to the recovery server **114** to resend video data packets.

In a particular embodiment, requests to resend lost packets and failed retransmissions may be monitored at the router **112** or at the recovery server **114**. Such requests provide information that enables estimation of video quality at the STBs **130**, **140**, **150**, and **160** without continually monitoring actual video data packet traffic. Monitored data may include a number of consecutive lost packets and intervals between packet losses. Other information that may be monitored includes packet loss ratio, latency, MPEG2 TS header impairment, or any other data associated with receiving video data multicast packets.

Estimates of video quality based solely on monitoring requests to the recovery server **114** may be limited by factors such as lost requests, single requests that are transmitted multiple times, multiple packets requested in a single request, or other factors. These estimates may be improved by including deep packet inspection at the monitoring device, such as at the router **112**. For example, deep packet inspection may identify multiple video data packets in a single request, may detect duplicate requests for a video data packet, or may otherwise improve accuracy of the video quality estimates.

The performance server **108** may receive data indicating one or more potential network failures based on monitoring the requests to the recovery server **114**. In response, the performance server **108** may instruct the direct monitoring of video data packet traffic at one or more affected receivers. For example, the performance server **108** may instruct the router **122** to monitor video packet traffic to the first STB **130** when requests for lost video packets sent by the first STB **130** indicate a potential network failure.

Using directly monitored video data packet traffic, a more accurate estimate of video quality at the receiver may be generated. The more accurate estimate may be used as a basis of further diagnostic measures if a network failure is detected. Additional information may be collected by other network elements to provide a more complete picture of network performance to detect and diagnose problems. For example, the performance server **108** may detect that video data packet traffic to a particular STB is impaired and may instruct all routers along the transmission path to monitor video data packet traffic to the STB. The resulting traffic data may be compared to stored traffic signatures associated with network failures to predict a source of the impairment.

In addition, the directly monitored video data packet traffic may be used to improve future estimates of video quality based on requests to the recovery server **114** by correlating retransmission request patterns and actual video data packet traffic patterns. Signatures or patterns of retransmission requests may be identified as being correlated to specific types of video data packet delivery failures, to general data packet delivery failure, to problematic, near-problematic, or non-problematic video quality at a receiver, or to any combination thereof.

The retransmission request data monitored at the router **112** or the recovery server **114**, as well as the actual video data packet traffic to the receivers, may be compiled by the performance server **114** and used to determine network performance trends and to predict network failures. For example, current hour performance may be compared with performance from a previous hour, a previous day, or other period to detect performance trends. To illustrate, a detected trend may reveal that some subscribers may have poor video quality between 8-9 μm every weekday. Proactive or remedial steps may be implemented to improve video quality to the subscribers. Video quality to individual subscribers, as well as overall network performance, can be maintained and improved by detecting and proactively addressing such trends.

In a particular embodiment, a knowledge base may be maintained and updated in response to network activity and trends. The knowledge base may be located at a single server or may be distributed throughout one or more networks as one or more discrete, interconnected, or replicated databases or other applications. In an illustrative embodiment, the knowledge base may be located at the performance server **108**.

Although the particular illustrative embodiment of the system **100** of FIG. **1** depicts a single acquisition server **104**, recovery server **114**, and four STBs **130**, **140**, **150**, and **160**, the system **100** can include any number of A-servers **104**, D-servers **114**, and multicast receiver devices such as STBs **130**, **140**, **150**, and **160**. Likewise, the system **100** can include additional servers, switches, routers, and other well-known network elements. Furthermore, although system **100** is illustrated as having routers **106**, **112**, **122**, and **124** to perform packet traffic inspection and monitoring, the system **100** may include one or more switches, hubs, gateways, servers, or other network device capable of functioning as a branching

point for multicast packet traffic. In addition, the system **100** may include multiple taps to perform packet inspection and monitoring.

In a particular embodiment, the system **100** may include an Internet Protocol Television (IPTV) system that is adapted to distribute multimedia content from multiple sources. The IPTV system can include a Super Video Head-End Office having multiple acquisition servers **104** to encode and distribute content from each source. The IPTV system can also include multiple Regional or Video Head-End Offices having multiple recovery servers **114** to distribute multimedia content to designated groups of multimedia receivers, such as the representative STBs **130**, **140**, **150**, and **160**. In a particular embodiment, the STBs **130**, **140**, **150**, and **160** can include IPTV set-top box devices, video gaming devices or consoles that are adapted to receive IPTV content, personal computers or other computing devices that are adapted to emulate set-top box device functionalities, another device adapted to receive IPTV content and transmit data to an FPTV system via an access network, or any combination thereof.

Referring to FIG. **2**, a particular illustrative embodiment of a system to monitor video data packet delivery is depicted and generally designated **200**. The system **200** includes a multicast server **202** in communication with a receiver **240** via a multicast branching device, such as a router **220**. The multicast server **202** and the receiver **240** are further in communication with a performance server **260** via the router **220**. The multicast server **202**, the receiver **240**, and the router **220** may operate in conjunction with a knowledge base **270** located at the performance server **260** to monitor multicast transmission performance data and to detect and diagnose network failures and to predict future network failures.

In a particular embodiment, the multicast server **202** includes a processor **204**, a memory **206**, a network interface **210**, a multicast module **212**, a retransmission module **214**, and a multicast server metric module **216**. In a particular embodiment, the memory **206** can include instructions that are executable by the processor **204**, such as one or more computer programs **208**.

The multicast module **212** may be executable by the processor **204** to send multimedia content to the receiver **240** via the network interface **210** and the router **220**. In a particular embodiment, the multicast module **212** may be executable by the processor **204** to transmit video data via IP multicast, using Real-time Transport Protocol (RTP), for example. In a particular embodiment, the multicast module **212** may be executable by the processor **204** to associate a multicast packet sequence number to each packet of a multicast transmission.

The retransmission module **214** may be executable by the processor **204** to receive a message from the receiver **240** requesting retransmission of packets that were not received. In a particular embodiment, the retransmission module **214** may be executable by the processor **204** to retransmit requested packets via an Internet Protocol (IP) unicast. In a particular embodiment, the retransmission module **214** may also be executable by the processor **204** to receive and process messages from other receivers (not shown).

The multicast server metric module **216** may be executable by the processor **204** to analyze the retransmission requests to detect performance data associated with one or more multicast transmissions from the multicast server **202**. In a particular embodiment, the multicast server metric module **216** may be executable by the processor **204** to record data related to a first number of video data packets of a multicast transmission that are not received by one or more multicast group members, such as the receiver **240**. In a particular embodiment the multicast server metric module **216** may be executable by the processor **204** to record data related to a second number of lost retransmission packets that are sent to multicast group members but not received. In a particular embodiment, the multicast server metric module **216** may be executable by the processor **204** to record performance data corresponding to individual multicast receivers, aggregated data corresponding to one or more multicast transmissions, aggregated data based on network topology, aggregated data based on a time period, or any combination thereof.

In a particular illustrative embodiment, the multicast server metric module **216** may be executable by the processor **204** to compare performance data to one or more thresholds associated with multicast performance. In a particular embodiment, the multicast server metric module **216** may be executable by the processor **204** to send a message to the performance server **260** when at least one of the first number of lost video data packets and the second number of lost retransmission packets meets or exceeds a threshold. For example, the threshold may include a number of lost packets, a number of lost packets in a predetermined time period, a percentage of sent packets that are not received, a number of lost retransmission packets, a number of lost retransmission packets in a predetermined time period, a percentage of requested retransmission packets that are not received, or any combination thereof. In addition, the threshold may include a percentage of multicast destinations experiencing packet losses that exceed one or more thresholds, a number of total packets lost for all multicast destinations, a number of total packets lost over one or more predetermined time periods, or any combination thereof.

In a particular embodiment, the multicast server metric module **216** may be executable by the processor **204** to determine a trend indicating an impending threshold event based on prior performance data. In a particular embodiment, the multicast server metric module **216** may be executable by the processor **204** to predict an amount of time before a threshold will be met or exceeded. In a particular embodiment, the multicast server metric module **216** may be executable by the processor **204** to compare the predicted amount of time to a threshold amount of time, and send a message to the performance server **260** when the threshold amount of time is met or exceeded.

In a particular embodiment, the receiver **240** may include a processor **242** coupled to a network interface **244**, a memory **246**, a buffer **248**, a packet request module **250**, and a metric module **252**. In a particular embodiment, the memory **246** may include instructions executable by the processor **242**, such as one or more computer programs **248**. In a particular embodiment, the receiver **240** may be adapted to receive P multicast packets via the network interface **244** and to store the multicast packets at the buffer **248**. In a particular embodiment, the receiver **240** may be a network device or end-user device adapted to receive multicast multimedia content, such as the recovery server **114** or the STB **130** illustrated in FIG. **1**.

The packet request module **250** may be executable by the processor **242** to access the buffer **248** and to detect one or more missing packets by examining multicast packet sequence identifiers or numbers of received packets. In a particular embodiment, the packet request module **250** may be executable by the processor **242** to generate and send a message to the multicast server **202** to request retransmission of the missing packets.

The receiver metric module **252** may be executable by the processor **242** to detect performance data associated with one or more multicast transmissions. In a particular embodiment, the receiver metric module **252** may be executable by the

processor **242** to record a first number of lost video packets of a multicast transmission from the multicast server **202**. In a particular embodiment, the receiver metric module **252** may be executable by the processor **242** to record a second number of lost retransmission packets that are requested from the multicast server **202** but not received.

In a particular embodiment, the receiver metric module **252** may be executable by the processor **242** to compare performance data to one or more thresholds associated with multicast performance. In a particular embodiment, the receiver metric module **252** may be executable by the processor **242** to send a message to the performance server **260** when at least one of the first number of lost video data packets and the second number of lost retransmission packets meets or exceeds a threshold. For example, the threshold may include a number of lost packets, a number of lost packets in a predetermined time period, a percentage of sent packets that are not received, a number of lost retransmission packets, a number of lost retransmission packets in a predetermined time period, a percentage of requested retransmission packets that are not received, or any combination thereof.

In a particular embodiment, the receiver metric module **252** may be executable by the processor **242** to determine a trend indicating an impending threshold event based on prior performance data. In a particular embodiment, the receiver metric module **252** may be executable by the processor **242** to predict an amount of time before a threshold will be met or exceeded. In a particular embodiment, the receiver metric module **252** may be executable by the processor **242** to compare the predicted amount of time to a threshold amount of time and to send a message to the performance server **260** when the threshold amount of time is met or exceeded.

In a particular embodiment the router **220** includes a processor **222**, a first network interface **223**, a second network interface **224**, a memory **226**, an inspection module **230**, and a router metric module **232**. In a particular embodiment, the memory **226** can include instructions that are executable by the processor **222**, such as one or more computer programs (CP) **228**.

In a particular embodiment, the router **220** is a multicast router that is adapted to receive multicast video data packets from the multicast server **202** via the first network interface **223** and to send multicast video data packets to multicast group members, such as to the receiver **240** via the second network interface **224**. In a particular embodiment, the router **220** is adapted to maintain and update multicast group information, such as by using Internet Group Management Protocol (IGMP).

The inspection module **230** may be executable by the processor **222** to perform deep packet inspection on packets received via the first network interface **223**, the second network interface **224**, or both. In a particular embodiment the inspection module **230** may be executable by the processor **222** to determine multicast sequence identifiers or numbers of one or more multicast packets received at the first network interface **223**. In a particular embodiment, the inspection module **230** may be executable by the processor **222** to inspect one or more packet redelivery requests from one or more multicast destinations, such as the receiver **240**, via the second network interface **224**. The inspection module **230** may be executable by the processor **222** to determine a sender of the redelivery request, one or more multicast video data packets that are requested, other information associated with the redelivery request, or any combination thereof. Such retransmission request information may be stored in the memory **226** and processed by the processor **222** periodically, upon request, when a count of retransmission requests exceeds a threshold, or any combination thereof.

The router metric module **232** may be executable by the processor **222** to determine performance data associated with one or more multicast transmissions received at the first network interface **223**. In a particular embodiment, the performance data may include a number of dropped packets at an input buffer (not shown) of the router **220**, a number of dropped packets at an output buffer (not shown) of the router **220**, a number of packet errors detected at the router **220**, a rate of packets received for one or more multicast groups, a total number of packets received for one or more multicast groups, other performance data associated with one or more multicast groups or transmissions, or any combination thereof.

In a particular embodiment, the router metric module **232** may be executable by the processor **222** to record performance data and to determine one or more trends based on the recorded performance data. In a particular embodiment, the router metric module **232** may be executable by the processor **222** to generate and send a warning to the performance server **260** when performance data is predicted to exceed a threshold.

In a particular embodiment, the router metric module **232** may be executable by the processor **222** to receive signature data **234** associated with one or more types of delivery failure. For example, the signature data **234** may include data having a rate of received multicast packets that decreases overtime correspond to a delivery failure upstream of the router **220**. As another illustrative, non-limiting example, the signature data **234** may include data indicating a number of discarded packets due to output buffer overflow increasing over time, which overflow may correspond to a delivery failure downstream from the router **220**. The router metric module **232** may be adapted to compare the monitored performance data to the stored signature data **234** to predict a future delivery failure, to identify a present delivery failure, to identify a cause of a real or predicted delivery failure, or any combination thereof.

In a particular embodiment, the router metric module **232** may be executable by the processor **222** to continually monitor performance data and to compare the performance data to the signature data **234**. The router metric module **232** may be executable by the processor **222** to send a warning to the performance server **260** when a delivery failure is predicted. In a particular embodiment, the router metric module **232** may be executable by the processor **222** to send at least a portion of the performance data to the performance server **260** when a request is received from the performance server **260**, such as to supply an additional layer of detail to the knowledge base **270** to diagnose a network delivery problem. In a particular embodiment, the router **220** may be adapted to add, replace, or update the signature data **234** with additional signature data received from the knowledge base **270** at the performance server **260**.

In a particular embodiment, the router metric module **232** may be executable by the processor **222** to only monitor and record particular performance data when a request for the particular performance data is received from the performance server **260**. In a particular embodiment, the request may indicate one or more types of data to monitor and one or more time periods for the router **220** to perform the monitoring. In a particular embodiment, the request may specify data related to multicast packet traffic, packet errors, dropped packets, data acquired by deep packet inspection, or any combination thereof.

The performance server **260** may include a processor **262**, a network interface **264**, a memory **266**, and a knowledge base

270. In a particular embodiment, the memory 266 can include instructions that are executable by the processor 262, such as one or more computer programs 268. In a particular embodiment, the performance server 260 is configured to communicate with one or more multicast servers including the multicast server 202, one or more network devices including the router 220, and one or more multicast destination devices including the receiver 240 via the network interface 264.

The knowledge base 270 may be executable by the processor 262 to receive network traffic data and other metric data and to compare the received data to data corresponding to distinct network traffic signatures to generate a proper response. In addition, the knowledge base 270 may store, update, and otherwise maintain signature data 272 that corresponds to various network problems. For example, the signature data 272 may be stored as one or more databases or other files at the memory 266. Instructions generated by the knowledge base 270 may be transmitted by the performance server 270 to recipients throughout the system 200. In a particular embodiment, the knowledge base 270 may be local instance of an intra-network or inter-network distributed knowledge base.

In a particular embodiment the knowledge base 270 may be executable by the processor 262 to receive data from the receiver 240 indicating a first number of multicast video data packets not received at the receiver 240, a second number of failed redelivery requests of the receiver 240, other performance data or metrics associated with video data packets, or any combination thereof. The knowledge base 270 may be executable by the processor 262 to determine that one or more thresholds are exceeded based on the received performance data. In a particular embodiment, the knowledge base 270 may be executable by the processor 262 to determine that one or more thresholds are exceeded based on aggregated performance data from multiple receivers, multicast servers, network devices, or any combination thereof.

In a particular embodiment, the knowledge base 270 may be executable by the processor 262 to query multiple network devices for performance metrics corresponding to multicast video data packets. For example, the knowledge base 270 may be executable by the processor 262 to instruct one or more multicast branching points between the multicast sever 202 and the receiver 240, including the router 220, to send performance data corresponding to multicast video data packets that are sent by the multicast server 202 to a multicast group that includes the receiver 240.

In a particular embodiment, the knowledge base 270 may be executable by the processor 262 to identify a delivery failure. In a particular embodiment, the knowledge base 270 may be executable by the processor to determine a cause of a delivery failure, such as a failed network card, by comparing current performance data to signature data 272. The signature data 272 may identify one or more packet delivery failure signatures based on recorded performance data preceding one or more prior delivery failures. In a particular embodiment, the knowledge base 270 may instead identify one or more delivery failures based at least partially on messages or warnings received from devices of the system 200, or only using received performance data without using signature data.

In a particular embodiment, the knowledge base 270 may be executable by the processor 262 to initiate a response to the delivery failure. In a particular embodiment, the response may include sending a notice to one or more administrators of the system 200, automatically redirecting network traffic, other responses appropriate to the delivery failure, or any combination thereof.

In a particular embodiment, the knowledge base 270 may be executable by the processor 262 to update the signature data 272 based at least partially on received performance data. The knowledge base 270 may be executable by the processor 262 to send at least a portion of the updated signature data 272 to one or more multicast video data packet monitoring devices, including the router 220.

During operation, data corresponding to one or more metrics relating to network performance may be communicated to the knowledge base 270 via the network interface 264. For example, the metrics may exhibit levels or trends indicating abnormal activity, the source of which has not been determined. The knowledge base 270 may be configured to store and maintain signature data 272 corresponding to various network problems. In a particular embodiment, data may come from the multicast server 202, the receiver 240, the router 220, a passive or active deep packet inspection network element such as one or more firewalls (not shown), one or more other network elements, or any combination thereof.

The knowledge base 270 may compare the received metric data to signature data 272 that is stored at the knowledge base. The knowledge base 270 may include signature matching logic (not shown) that uses techniques such as pattern recognition and matching to determine whether the received metric data corresponds to one or more signatures of the signature data 272 within a particular confidence level.

Each signature may represent a pattern of activity corresponding to a particular event. For example, the signature data 272 may maintain one or more signatures that correspond to network traffic patterns and network metric data that occur when a network card fails. Other signatures may correspond to traffic patterns and network metric data that are detected upon the failure or diminished performance of other network elements, such as servers, receivers, transmission lines, routers, other network elements, or any combination thereof. In addition, other signatures may correspond to external sources of network abnormalities, such as sun spots, power outages, and severed transmission lines, as illustrative, non-limiting examples

In a particular embodiment, the knowledge base 270 may be configured to receive both stateful metric data and stateless metric data, as well as to store and maintain signature having stateful data, stateless data, or any combination thereof. As an example, a network element may detect that a multicast traffic flow has a multicast packet rate beneath a threshold, and may send the stateless data (i.e., traffic rate) to the knowledge base. However, a network element using deep packet inspection may further be able to identify state data such as specific sequence numbers of dropped or transmitted multicast video data packets, and may send stateful metric data (e.g., a number of consecutive dropped packets based on packet sequence number) to the knowledge base 270. As another example, a network element may be able to send not only a current metric value, but also historical values of the metric to enable the knowledge base 270 to associate trending data with a signature.

The knowledge base 270 may be configured to provide multiple detail layers of signature pattern matching. For example, an initial message to the knowledge base 270 may include only key metric points, such as multicast discards, multicast errors, video data packet retransmission requests, or other key measurements. If the metric information that is provided to the knowledge base 270 in the initial request matches multiple signatures above a specified degree of certainty, such as above a predetermined correlation threshold, the knowledge base 270 may not be able to determine a single result. The knowledge base 270 may therefore request addi-

tional measurements or metric data for further comparisons. This process may be repeated until a sufficiently detailed amount of data has been provided that enables the knowledge base **270** to identify a signature within a predetermined confidence level, or until it is determined that the uncertainty cannot be resolved. A specific illustrative example of multiple detail levels of signature matching is provided in conjunction with the performance server **108** illustrated in FIG. **1**, instructing the router **122** to monitor video packet traffic (i.e., a second detail level) when requests for lost video packets sent by the first STB **130** (i.e., a first detail level) indicate a potential network failure.

When a signature has been determined to match the received data within a desired confidence level, a source of the abnormal activity that is associated with the determined signature may be provided to an appropriate responder. For example, if a failed network element has been determined to be the source of abnormal network activity, the knowledge base **270** may initiate a work order that identifies the failed network element to be replaced.

In addition, the knowledge base **270** may include extrapolation logic (not shown) to predict one or more sources of network problems based on received data. For example, received data indicating intermittent periods of multicast delivery failure along a particular multicast branch may be diagnosed as matching the signature of a multicast router that will fail within the next twenty-four hours. Thus, the knowledge base **270** may predict impending failures and may proactively initiate notices or work orders for repair, reducing network downtime and improving overall service and content delivery.

Individual signatures of the signature data **272** may be created and maintained based on technical knowledge, machine learning techniques, other sources of information, or any combination thereof. For example, when a new type of network element is introduced to the system **200**, the provider of the network element may supply signature data that identifies various failure modes of the new network element. However, in a particular embodiment the signature data supplied by the provider of the network element may be adaptive to actual data measured in conjunction with actual physical failures of the network element.

In a particular embodiment, the knowledge base **270** stores requests including traffic and metric data identifying abnormal behavior as a knowledge base request file (not shown) at the memory **266**. When a source of the abnormal behavior is diagnosed from the signature data **272** via pattern recognition or other comparison techniques, a work order may be initiated, and corresponding data may also be stored at the knowledge base request file. When the actual source of the abnormal behavior is determined, such as by a technician replacing, repairing, or otherwise identifying the problem source, the knowledge base request file may be updated and used to improve the knowledge base **270** via a feedback process that updates or modifies the signature data **272**.

For example, when the knowledge base **270** predicts cause "A" for a particular behavior but the actual cause is determined to be "B," a signature for "A" may be modified to discount future predictions based on similar data to the data stored at the knowledge base request file. Similarly, the signature for "B" may be modified to increase future predictions based on the same data. In an illustrative embodiment, the feedback process may include generating a training set to train one or more neural networks to refine knowledge base predictions based on the traffic and metric data.

In a particular embodiment, when a source of an abnormality is determined that is not currently identified in the signature data **272**, a new signature file may be generated using the data stored in the knowledge base request file. As additional network abnormalities are diagnosed as having a corresponding source, the new signature file may be updated to improve future predictions.

In addition to a feedback process, the signature data **272** may also be updated based on other criteria. For example, a particular signature that has not generated a corresponding prediction in a specified amount of time, such as three years, may be identified as an outdated or obsolete signature, and may be archived or simply deleted. As another example, signature files may be added or deleted based on the addition or removal of network elements.

In addition, in a particular embodiment, the knowledge base **270** may distribute the signature data **272** to network elements such as the router **220**, the multicast server **202**, and the receiver **240**. To conserve network resources, the distributed data may only contain high-level or coarse signature information for preliminary detection of abnormalities by the network elements. Upon detection of a potential abnormality by comparison with local signature data, the network element may forward the traffic or metric data to the knowledge base **270** for further analysis.

Referring to FIG. **3**, an illustrative embodiment of an Internet Protocol Television (IPTV) system that may be used monitor video data packet delivery is illustrated and is generally designated **300**. As shown, the system **300** can include a client facing tier **302**, an application tier **304**, an acquisition tier **306**, and an operations and management tier **308**. Each tier **302**, **304**, **306**, **308** is coupled to a private network **310**; to a public network **312**, such as the Internet; or to both the private network **310** and the public network **312**. For example, the client-facing tier **302** can be coupled to the private network **310**. Further, the application tier **304** can be coupled to the private network **310** and to the public network **312**. The acquisition tier **306** can also be coupled to the private network **3310** and to the public network **312**. Additionally, the operations and management tier **308** can be coupled to the public network **312**.

As illustrated in FIG. **3**, the various tiers **302**, **304**, **306**, **308** communicate with each other via the private network **310** and the public network **312**. For instance, the client-facing tier **302** can communicate with the application tier **304** and the acquisition tier **306** via the private network **310**. The application tier **304** can communicate with the acquisition tier **306** via the private network **310**. Further, the application tier **304** can communicate with the acquisition tier **306** and the operations and management tier **308** via the public network **312**. Moreover, the acquisition tier **306** can communicate with the operations and management tier **308** via the public network **312**. In a particular embodiment, elements of the application tier **304**, including, but not limited to, a client gateway **350**, can communicate directly with the client-facing tier **302**.

The client-facing tier **302** can communicate with user equipment via an access network **366**, such as an Internet Protocol Television (IPTV) access network. In an illustrative embodiment, customer premises equipment (CPE) **314**, **322** can be coupled to a local switch, router, or other device of the access network **366**, such as a first representative router **370**. The client-facing tier **302** can communicate with a first representative set-top box device **316** via the first CPE **314** and with a second representative set-top box device **324** via the second CPE **322**. In a particular embodiment, the first representative set-top box device **316** and the first CPE **314** can be located at a first customer premise, and the second representative set-top box device **324** and the second CPE **322** can be located at a second customer premise. In another particular

embodiment, the first representative set-top box device **316** and the second representative set-top box device **324** can be located at a single customer premise, both coupled to one of the CPE **314**, **322**. The CPE **314**, **322** can include routers, local area network devices, modems, such as digital subscriber line (DSL) modems, any other suitable devices for facilitating communication between a set-top box device and the access network **366**, or any combination thereof.

In an exemplary embodiment, the client-facing tier **302** can be coupled to the CPE **314**, **322** via fiber optic cables. In another exemplary embodiment the CPE **314**, **322** can be digital subscriber line (DSL) modems that are coupled to one or more network nodes via twisted pairs, and the client-facing tier **302** can be coupled to the network nodes via fiber-optic cables. Each set-top box device **316**, **324** can process data received via the access network **366**, via an IPTV software platform, such as Microsoft® TV IPTV Edition.

The first set-top box device **316** can be coupled to a first external display device, such as a first television monitor **318**, and the second set-top box device **324** can be coupled to a second external display device, such as a second television monitor **326**. Moreover, the first set-top box device **316** can communicate with a first remote control **320**, and the second set-top box device **324** can communicate with a second remote control **328**. The set-top box devices **316**, **324** can include IPTV set-top box devices; video gaming devices or consoles that are adapted to receive IPTV content; personal computers or other computing devices that are adapted to emulate set-top box device functionalities; any other device adapted to receive IPTV content and transmit data to an IPTV system via an access network; or any combination thereof.

In an exemplary, non-limiting embodiment, each set-top box device **316**, **324** can receive data, video, or any combination thereof, from the client-facing tier **302** via the access network **366** and render or display the data, video, or any combination thereof, at the display device **318**, **326** to which it is coupled. In an illustrative embodiment, the set-top box devices **316**, **324** can include tuners that receive and decode television programming signals or packet streams for transmission to the display devices **318**, **326**. Further, the set-top box devices **316**, **324** can include a STB processor **370** and a STB memory device **372** that is accessible to the STB processor **370**. In one embodiment, a computer program, such as the STB computer program **374**, can be embedded within the STB memory device **372**.

In a particular embodiment, the set-top box devices **316**, **324** can be adapted to record performance data associated with receiving media content such as multicast video data packet streams from the access network **366**. The set-top box devices **316**, **324** may be adapted to determine that a performance threshold has been reached or will soon be reached, and to send a warning of the threshold event via the access network **366**. In an illustrative embodiment, the threshold event can correspond to video data packets that are not received, failed redelivery requests for lost video data packets, other metrics associated with receiving video data at the set-top box devices **316**, **324**, or any combination thereof.

In an illustrative embodiment, the client-facing tier **302** can include a client-facing tier (CFT) switch **330** that manages communication between the client-facing tier **302** and the access network **366** and between the client-facing tier **302** and the private network **310**. As illustrated, the CFT switch **330** is coupled to one or more data servers, such as U-servers **332**, that store, format, encode, replicate, or otherwise manipulate or prepare video content for communication from the client-facing tier **302** to the set-top box devices **316**, **324**. The CFT switch **330** can also be coupled to a terminal server **334** that provides terminal devices with a point of connection to the IPTV system **300** via the client-facing tier **302**. In a particular embodiment, the CFT switch **330** can be coupled to a video-on-demand (VOD) server **336** that stores or provides VOL) content imported by the IPTV system **300**. Further, the CFT switch **330** is coupled to one or more video servers **380** that receive video content and transmit the content to the set-top boxes **316**, **324** via the access network **366**. In a particular embodiment, the video servers **380** or the D-servers **332** may be adapted to compare performance data associated with delivery of video data via the access network **366** to one or more performance thresholds, and to generate a warning message when the performance data indicates that a performance threshold has been or is predicted to be exceeded. Performance data may include video data packets not received at the video servers **380** or the D-servers **332**, or video data packets sent by the video servers **380** but not received at one or more of the set-top box devices **316**, **324**. Performance data may also include failed requests for redelivery of video data packets. The failed requests can be sent by the video servers **380** or the D-servers **332**, or sent by the set-top box devices **316**, **324** to the video servers **380**.

In an illustrative embodiment, the client-facing tier **302** can communicate with a large number of set-top boxes, such as the representative set-top boxes **316**, **324**, over a wide geographic area, such as a metropolitan area, a viewing area, a statewide area, a regional area, a nationwide area or any other suitable geographic area, market area, or subscriber or customer group that can be supported by networking the client-facing tier **302** to numerous set-top box devices. In a particular embodiment, the CFT switch **330**, or any portion thereof, can include a multicast router or switch that communicates with multiple set-top box devices via a multicast-enabled network.

In a particular embodiment, the CFT switch **230**, the first router **370** and other routers or switches (not shown) of the access network **366** can function as multicast branching points for transmissions from the video servers **380** to set-top box devices **316**, **324**. In a particular embodiment, one or more of the multicast branching points, such as the first router **370**, may be adapted to monitor performance metrics such as packet discards, packet errors, and packet traffic associated with individual multicasts. Performance metrics exceeding threshold values, or predicted to exceed threshold values, may cause a warning to be generated and sent to a network monitoring system. In a particular embodiment, the first router **370** may be adapted to perform deep packet inspection to acquire and monitor additional data associated with multicast video data delivery.

As illustrated in FIG. **3**, the application tier **304** can communicate with both the private network **310** and the public network **312**. The application tier **304** can include a first application tier (APP) switch **338** and a second APP switch **340**. In a particular embodiment, the first APP switch **338** can be coupled to the second APP switch **340**. The first APP switch **338** can be coupled to an application server **342** and to an OSS/BSS gateway **344**. In a particular embodiment, the application server **342** can provide applications to the set-top box devices **316**, **324** via the access network **366**, which enable the set-top box devices **316**, **324** to provide functions, such as interactive program guides, video gaming, display, messaging, processing of VOD material and other IPTV content, etc. In an illustrative embodiment, the application server **342** can provide location information to the set-top box devices **316**, **324**. In a particular embodiment, the OSS/OSS gateway **344** includes operation systems and support (OSS) data, as well as billing systems and support (BSS) data. In one

embodiment, the OSS43SS gateway **344** can provide or restrict access to an OSS/BSS server **364** that stores operations and billing systems data.

The second APP switch **340** can be coupled to a domain controller **346** that provides Internet access, for example, to users at their computers **368** via the public network **312**. For example, the domain controller **346** can provide remote Internet access to IPTV account information, e-mail, personalized Internet services, or other online services via the public network **312**. In addition, the second APP switch **340** can be coupled to a subscriber and system store **348** that includes account information, such as account information that is associated with users who access the IPTV system **300** via the private network **310** or the public network **312**. In an illustrative embodiment, the subscriber and system store **348** can store subscriber or customer data and create subscriber or customer profiles that are associated with IP addresses, stock-keeping unit (SKU) numbers, other identifiers, or any combination thereof, of corresponding set-top box devices **316**, **324**. In another illustrative embodiment, the subscriber and system store **348** can store data associated with capabilities of set-top box devices associated with particular customers. In a particular embodiment, the subscriber and system store **348** can store data associated with one or more quality of service levels for various set-top box devices associated with particular customers. Packet delivery performance thresholds for each set-top box device may be determined at least partially based on the quality of service data.

In a particular embodiment, the application tier **304** can include a client gateway **350** that communicates data directly to the client-facing tier **302**. In this embodiment the client gateway **350** can be coupled directly to the CFT switch **330**. The client gateway **350** can provide user access to the private network **310** and the tiers coupled thereto. In an illustrative embodiment, the set-top box devices **316**, **324** can access the IPTV system **300** via the access network **366**, using information received from the client gateway **350**. User devices can access the client gateway **350** via the access network **366**, and the client gateway **350** can allow such devices to access the private network **310** once the devices are authenticated or verified. Similarly, the client gateway **350** can prevent unauthorized devices, such as hacker computers or stolen set-top box devices from accessing the private network **310**, by denying access to these devices beyond the access network **366**.

For example, when the first representative set-top box device **316** accesses the client-facing tier **302** via the access network **366**, the client gateway **350** can verify subscriber information by communicating with the subscriber and system store **348** via the private network **310**. Further, the client gateway **350** can verify billing information and status by communicating with the OSS/**0535** gateway **344** via the private network **310**. In one embodiment, the OSS/BSS gateway **344** can transmit a query via the public network **312** to the OSS/BSS server **364**. After the client gateway **350** confirms subscriber and/or billing information, the client gateway **350** can allow the set-top box device **316** to access IPTV content and VOD content at the client-facing tier **302**. If the client gateway **350** cannot verify subscriber information for the set-top box device **316**, e.g., because it is connected to an unauthorized twisted pair, the client gateway **350** can block transmissions to and from the set-top box device **316** beyond the access network **366**.

As indicated in FIG. **3**, the acquisition tier **306** includes an acquisition tier (AQT) switch **352** that communicates with the private network **310**. The AQT switch **352** can also communicate with the operations and management tier **308** via the public network **312**. In a particular embodiment the AQT switch **352** can be coupled to a live acquisition server **354** that receives or acquires television content, movie content, advertisement content, other video content, or any combination thereof, from a broadcast service **356**, such as a satellite acquisition system or satellite head-end office. In a particular embodiment, the live acquisition server **354** can transmit content to the AQT switch **352**, and the AQT switch **352** can transmit the content to the CFT switch **330** via the private network **310**. In a particular embodiment, the content can be sent via IP multicast via one or more network devices, such as a second representative router **311**, adapted to monitor multicast performance metrics and to report when the performance metrics exceed or are expected to exceed threshold values.

In an illustrative embodiment, content can be transmitted to the D-servers **332**, where it can be encoded, formatted, stored, replicated, or otherwise manipulated and prepared for communication from the video server(s) **380** to the set-top box devices **316**, **324**. The CFT switch **330** can receive content from the video server(s) **380** and communicate the content to the CPE **314**, **322** via the access network **366**. The set-top box devices **316**, **324** can receive the content via the CPE **314**, **322**, and can transmit the content to the television monitors **318**, **326**. In an illustrative embodiment, video or audio portions of the content can be streamed to the set-top box devices **316**, **324**. In an illustrative embodiment, the live acquisition server **354** can send the content via IP multicast, and can monitor delivery metrics such as lost packets and failed packet retransmission attempts.

Further, the AQT switch **352** can be coupled to a video-on-demand importer server **358** that receives and stores television or movie content received at the acquisition tier **306** and communicates the stored content to the VOL) server **336** at the client-facing tier **302** via the private network **310**. Additionally, at the acquisition tier **306**, the video-on-demand (VOD) importer server **358** can receive content from one or more VOL sources outside the IPTV system **300**, such as movie studios and programmers of non-live content. The VOL) importer server **358** can transmit the VOD content to the AQT switch **352**, and the AQT switch **352**, in turn, can communicate the material to the CFT switch **330** via the private network **310**. The VOL) content can be stored at one or more servers, such as the VOD server **336**.

When users issue requests for VOD content via the set-top box devices **316**, **324**, the requests can be transmitted over the access network **366** to the VOL) server **336**, via the CFT switch **330**. Upon receiving such requests, the VOL) server **336** can retrieve the requested VOD content and transmit the content to the set-top box devices **316**,**324** across the access network **366**, via the CFT switch **330**. The set-top box devices **316**, **324** can transmit the VOD content to the television monitors **318**, **326**. In an illustrative embodiment, video or audio portions of VOD content can be streamed to the set-top box devices **316**, **324**.

FIG. **3** further illustrates that the operations and management tier **308** can include an operations and management tier (OMT) switch **360** that conducts communication between the operations and management tier **308** and the public network **312**. In the embodiment illustrated by FIG. **3**, the OMT switch **360** is coupled to a TV2 server **362**. Additionally, the OMT switch **360** can be coupled to an OSS/BSS server **364** and to a simple network management protocol (SNMP) monitor **386** that monitors network devices within or coupled to the IPTV system **300**. In a particular embodiment, the OMT switch **360** can communicate with the AQT switch **352** via the public network **312**.

In a particular embodiment, the SNMP monitor **386** can be adapted to receive delivery performance warnings or data from the set-top box devices **316**, **324**, the D-servers **332**, the video servers **380**, the live acquisition server **354**, and multicast switching devices such as the routers **311**, **370**, the CFT switch **330**, and the AQT switch **352**. In addition, the SNMP monitor **386** can receive performance warnings or data from one or more taps along multicast paths, such as the tap **170** of FIG. **1**. In a particular embodiment, the SNMP monitor **386** can query one or more devices for additional performance data to diagnose a multicast delivery failure. In a particular embodiment, the system **300** may further include one or more performance servers (not shown), such as the performance server **260** of FIG. **2**, to perform additional monitoring and diagnostic functions associated with multicast content delivery throughout the system **300**. In a particular embodiment, the system **300** may include one or more knowledge bases to maintain and update signature files associated with specific network delivery failures, such as the knowledge base **270** illustrated in FIG. **2**.

In an illustrative embodiment, the live acquisition server **354** can transmit content to the AQT switch **352**, and the AQT switch **352**, in turn, can transmit the content to the OMT switch **360** via the public network **312**. In this embodiment, the OMT switch **360** can transmit the content to the TV2 server **362** for display to users accessing the user interface at the TV2 server **362**. For example, a user can access the TV2 server **362** using a personal computer **368** coupled to the public network **312**.

Referring to FIG. **4**, a flow chart of a particular illustrative embodiment of a method of monitoring video packet delivery is depicted and generally designated **400**. Requests for retransmission of video data packets to a receiver may be monitored, at **402**. The requests may be sent to a server that resends lost multicast packets, such as the recovery server **114** of FIG. **1**. In a particular embodiment, the requests may be sent by one or more set-top box devices, such as the STBs **130**, **140**, **150**, and **160** of FIG. **1**.

Moving to **404**, a potential problem may be identified based on a pattern of requests from the receiver. For example, a potential problem may be identified based on a number of requests for video packet retransmission, an interval between consecutive requests, a ratio of requested packets, other metrics that may exceed a threshold value, or any combination thereof.

Continuing to **406**, video data packet traffic to the receiver may be monitored. For example, traffic data may be collected at a router or tap near the receiver and monitored at a performance server, such as the performance server **108** of FIG. **1**. Advancing to **408**, video quality at the receiver may be estimated based on the monitored video data packet traffic. Progressing to **410**, a correlation between video quality at the receiver and the pattern of requests for resending video data packets may be updated to improve future video quality estimates.

Moving to decision step **412**, a determination may be made whether a video quality problem is detected. As an illustrative, non-limiting example, a video quality problem may be detected if a number of lost packets per unit time exceeds a threshold. In a particular embodiment, when a video quality problem is detected, processing continues to **414**, where data is concurrently monitored at multiple points along the multicast route from a multicast server to the receiver to locate or diagnose the problem. Advancing to **416**, remedial actions may be performed to correct the problem.

Otherwise, when a video quality problem is not detected at **412**, a determination may be made whether a problem is impending, at **418**. For example, an impending problem may be detected when one or more performance metrics exhibit a trend indicating a threshold value may be exceeded within a particular time period. When a determination is made that a problem is impending, proactive actions may be performed, at **420**. Processing returns to **402**, where requests for retransmission of video data packets are monitored.

Referring to FIG. **5**, a flow chart of a second illustrative embodiment of a method of monitoring video packet delivery is depicted and generally designated **500**. In a particular embodiment, the method **500** illustrates an example of using signature files of a knowledge base, such as the signature data **272** of the knowledge base **270** depicted in FIG. **2**, in conjunction with elements of the method **400** depicted in FIG. **4**.

Requests for retransmission of video data packets to a receiver may be monitored, at **502**. The requests may be sent to a server that resends lost multicast packets, such as the retransmission module **214** of the multicast server **202** depicted in FIG. **2**. In a particular embodiment the requests may be sent by one or more receiver devices, such as the receiver **240** depicted in FIG. **2**. The receiver devices may be set-top box devices, such as STBs **130** of FIG. **1**.

Moving to **504**, a potential problem may be identified based on a pattern of requests from the receiver by using signatures in a knowledge base to assist in problem identification. For example, a potential problem may be identified based on a number of requests for video packet retransmission, an interval between consecutive requests, a ratio of requested packets, other metrics that may individually or collectively be compared against the signatures stored at the knowledge base, or any combination thereof. In a particular embodiment, any or all of the above metrics may be provided to the knowledge base, which may perform pattern matching to identify one or more signature files corresponding to the pattern of requests and identifying a particular potential problem.

Continuing to **506**, video data packet traffic to the receiver may be monitored. For example, when the identified signature files matching the pattern of request identifies one or more particular potential problems, the knowledge base may generate instructions to one or more network elements, such as the router **220**, to collect traffic data near the receiver and to send the traffic data to the knowledge base. Advancing to **508**, a determination of whether video quality at the receiver is impaired based on signatures at the knowledge base may be made. Progressing to **510**, all available data is gathered and used to update and store at the knowledge base correlation data between video data packet requests, packet traffic, and video quality at the receiver, and to make a final determination of whether a video quality problem exists.

Moving to decision step **512**, a determination may be made whether a video quality problem is detected. As an illustrative, non-limiting example, a video quality problem may be detected when the pattern of requests or the packet traffic, or both, match one or more signature files at the knowledge base within a certain degree of confidence. In a particular embodiment, when a video quality problem is detected, processing continues to **514**, where the knowledge base may receive an additional layer of detail concerning the detected problem in the form of data generated by concurrently monitoring packet traffic at multiple points along the multicast route from a multicast server to the receiver to locate or diagnose the problem. The data acquired by concurrent monitoring may be compared to the signature files at the knowledge base to diagnose and locate a cause of the detected video quality problem.

Advancing to **516**, remedial actions may be performed to correct the problem. For example, the knowledge base may initiate a repair process, such as by generating a work order to replace or repair a malfunctioning network element.

Otherwise, when a video quality problem is not detected at **512**, a determination may be made whether a problem is impending, at **518**. For example, an impending problem may be detected by comparing all available data to signature files that indicate impending problems. Examples of signature files that may represent impending problems may include signature files reflecting an intermittent malfunction, a reduced capacity, or an upward trend in delivery failures. When a determination is made that a problem is impending, proactive actions may be performed, at **520**.

Continuing to **522**, after either remedial actions are performed at **516** or proactive actions are performed at **520**, signatures in the knowledge base may be updated based on additional information acquired while performing the proactive or remedial actions. For example, a technician dispatched to replace a malfunctioning network element may instead discover another cause of the video quality problem. The actual cause may be associated with all corresponding data used to diagnose the problem in the knowledge base, and one or more signature files of the knowledge base may be updated to improve future diagnoses at the knowledge base. Updating the signature files may include adding new signature files when the cause is not yet associated with a signature file in the knowledge base. Processing returns to **502**, where requests for retransmission of video data packets are monitored. In a particular embodiment, an accuracy of the knowledge base in detecting or diagnosing network delivery problems may improve with increased usage of the knowledge base and feedback operations, such as performed at **510** and **522**.

Referring to FIG. **6**, a flow chart of a third illustrative embodiment of a method of monitoring video packet delivery is depicted and generally designated **600**. At **602**, in a particular embodiment, a warning is received from one or more network devices. The warning may indicate a trend associated with multicast video data packets. In a particular embodiment, the warning may indicate a prediction that a rate of loss of the multicast video data packets will exceed a threshold. In a particular embodiment, the warning may indicate a prediction that a number of failed packet recovery requests will exceed a threshold.

In a particular embodiment, the warning may be received from a network device does not include a switch or router. In an illustrative embodiment, the warning may be received at a knowledge base server of a multimedia content delivery system, such as the performance server **260** hosting the knowledge base **270** of FIG. **2**.

Continuing to **604**, in a particular embodiment, a threshold event corresponding to receiving video data packets at the multicast destination from a video server may be determined. In a particular embodiment, the threshold event may correspond to a number of multicast video data packets that are not received at the multicast destination. In another embodiment, the threshold event may correspond to a number of failed packet recovery requests.

Advancing to **606**, multiple network devices may be queried for performance metrics corresponding to multicast video data packets, the multicast video data packets sent from a video server of an internet protocol television system to a multicast destination. The network devices may include multicast branching points between the video server and the multicast destination. In a particular embodiment, the performance metrics may include a traffic metric associated with the multicast video data packets, a dropped packet metric, a packet error metric, or any combination thereof.

Moving to **608**, a delivery failure is identified based on the performance metrics. Progressing to **610**, a response to the delivery failure is initiated. In an illustrative embodiment, the response may include notifying one or more system administrators, redirecting network traffic, performing other remedial functions, or any combination thereof.

Continuing to **612**, in a particular embodiment, instructions may be sent to each of the network devices to substantially simultaneously record data associated with the performance metrics during a specified time interval. Advancing to **614**, in a particular embodiment performance data may be received from at least one of the network devices. The performance data may correspond to a time period prior to the delivery failure.

Moving to **616**, in a particular embodiment, at least one signature associated with the delivery failure may be generated based at least partially on the performance data. Progressing to **618**, in a particular embodiment data corresponding to the at least one signature may be sent to one or more of the network devices. The method terminates at **620**.

Referring to FIG. **7**, a flow chart of a fourth illustrative embodiment of a method of monitoring video packet delivery is depicted and generally designated **700**. At **702**, video data packets may be monitored in transit to a multicast destination, the video data packets associated with an internet protocol (IP) multicast transmission. In a particular embodiment, the monitoring may be performed by a network device, such as the router **220** of FIG. **2**.

Continuing to **704**, performance data associated with a performance metric based on the video data packets may be recorded.

In a particular embodiment, the video data packets may include multicast video data packets. Bach of the multicast video data packets may have a distinct sequence number associated with the IP multicast transmission. Progressing to **706**, in a particular embodiment, at least some of the multicast video data packets may be inspected. Continuing to **708**, in a particular embodiment, the router may determine that at least one multicast video data packet is lost based at least partially on sequence numbers of inspected packets. Advancing to **710**, in a particular embodiment, lost packet data corresponding to the IP multicast transmission may be recorded.

Moving to **712**, in a particular embodiment, data packets sent to a video server from the multicast destination may be inspected. Progressing to **714**, a request from the multicast destination to retransmit a first multicast video data packet may be identified. Continuing to **716**, retransmission request data corresponding to the request may be recorded.

Advancing to **718**, in a particular embodiment, the retransmission request data may be compared to the lost packet data to determine at least one of an upstream delivery failure and a downstream delivery failure. To illustrate, a packet requested for retransmission but not included in the lost packet data was lost downstream of the router, i.e., between the router and the multicast destination. In contrast, a packet requested for retransmission that is included in the lost packet data was lost upstream of the router, i.e., between the router and the video server.

In a particular embodiment, the video data packets further include a unicast video data packet sent to the multicast destination to replace a lost multicast video data packet. Moving to **720**, the unicast video data packet may be inspected. Progressing to **722**, retransmission data corresponding to the unicast video data packet may be recorded.

Continuing to **724**, a trend may be determined based on the performance data. Progressing to **726**, a warning may be sent to a server, the warning identifying the performance metric and a threshold. The warning may indicate a threshold crossing alert or potential problem identified by a signature in a performance server knowledge base, such as the knowledge base **270** of the performance server **260** depicted in FIG. **2**. The method terminates at **728**.

Referring to FIG. **8**, an illustrative embodiment of a general computer system is shown and is designated **800**. The computer system **800** can include a set of instructions that can be executed to cause the computer system **800** to perform any one or more of the methods or computer based functions disclosed herein. The computer system **800** may operate as a standalone device, or may be connected, e.g., using a network, to other computer systems or peripheral devices, such as a multimedia content distribution system, an Internet Protocol Television (IPTV) system, a server system, such as a video server, a D-server, an A-server, or a performance server, a content source, a multimedia receiver, a set-top box device, a multicast router, switch or other network device, other devices, or any combination thereof. Additionally, in a particular illustrative embodiment, the computing system **800** can communicate with other computing devices via a local area network, a wireless network, or a public network, such as the Internet.

In a networked deployment, the computer system may operate in the capacity of a server or as a client user computer in a server-client user network environment, or as a peer computer system in a peer-to-peer (or distributed) network environment. The computer system **800** can also be implemented as or incorporated into various devices, such as a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile device, a palmtop computer, a laptop computer, a desktop computer, a communications device, a wireless telephone, a land-line telephone, a control system, a camera, a scanner, a facsimile machine, a printer, a pager, a personal trusted device, a web appliance, a network router, switch or bridge, or any other machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. In a particular embodiment, the computer system **800** can be implemented using electronic devices that provide voice, video or data communication. Further, while a single computer system **800** is illustrated, the term "system" shall also be taken to include any collection of systems or sub-systems that individually or jointly execute a set, or multiple sets, of instructions to perform one or more computer functions.

In conjunction with the disclosed systems and methods, a video content delivery system enables proactive administration based on IP multicast transmission performance monitored at multiple points along a multicast transmission route. Various metrics may be used by different system resources to detect or predict multicast performance problems, and to notify a performance server of the actual or projected failure.

Video servers or set-top box devices may detect and record performance metrics including lost multicast packets or failed redelivery attempts. When the performance metrics are projected to exceed a threshold based on a trend, a warning may be sent to a performance server of the expected delivery failure.

The performance server may instruct network devices along the IP multicast transmission route to record and provide performance data relating to multicast video data packets, such as packet errors, dropped packets, and packet traffic. The network devices may be instructed to provide performance data for a specified time period, which may be combined at the performance server to generate a snapshot of multicast packet traffic along all or a part of a multicast transmission route. Problems such as failing network resources may be located and diagnosed, and corrective actions taken.

In addition, the network devices may monitor performance data for comparison to one or more delivery failure signatures. When the network device determines that the performance data indicates an impending delivery failure based on a similarity to one or more failure signatures, a warning may be sent to the performance server for corrective action.

As illustrated in FIG. **8**, the computer system **800** may include a processor **802**, e.g., a central processing unit (CPU), a graphics processing unit (GPU), or both. Moreover, the computer system **800** can include a main memory **804** and a static memory **806**, that can communicate with each other via a bus **808**. As shown, the computer system **800** may further include a video display unit **810**, such as a liquid crystal display (LCD), an organic light emitting diode (OLED), a flat panel display, a solid state display, or a cathode ray tube (CRT). Additionally, the computer system **800** may include an input device **812**, such as a keyboard, and a cursor control device **814**, such as a mouse. The computer system **800** can also include a disk drive unit **816**, a signal generation device **818**, such as a speaker or remote control, and a network interface device **820**.

In a particular embodiment, as depicted in FIG. **8**, the disk drive unit **816** may include a computer-readable medium **822** in which one or more sets of instructions **824**, e.g. software, can be embedded. Further, the instructions **824** may embody one or more of the methods or logic as described herein. In a particular embodiment, the instructions **824** may reside completely, or at least partially, within the main memory **804**, the static memory **806**, and/or within the processor **802** during execution by the computer system **800**. The main memory **804** and the processor **802** also may include computer-readable media.

In an alternative embodiment, dedicated hardware implementations, such as application specific integrated circuits, programmable logic arrays and other hardware devices, can be constructed to implement one or more of the methods described herein. Applications that may include the apparatus and systems of various embodiments can broadly include a variety of electronic and computer systems. One or more embodiments described herein may implement functions using two or more specific interconnected hardware modules or devices with related control and data signals that can be communicated between and through the modules, or as portions of an application-specific integrated circuit. Accordingly, the present system encompasses software, firmware, and hardware implementations.

In accordance with various embodiments of the present disclosure, the methods described herein may be implemented by software programs executable by a computer system. Further, in an exemplary, non-limited embodiment, implementations can include distributed processing, component/object distributed processing, and parallel processing. Alternatively, virtual computer system processing can be constructed to implement one or more of the methods or functionality as described herein.

The present disclosure contemplates a computer-readable medium that includes instructions **824** or receives and executes instructions **824** responsive to a propagated signal, so that a device connected to a network **826** can communicate voice, video or data over the network **826**. Further, the instructions **824** may be transmitted or received over the network **826** via the network interface device **820**.

While the computer-readable medium is shown to be a single medium, the term "computer-readable medium" includes a single medium or multiple media, such as a centralized or distributed database, and/or associated caches and servers that store one or more sets of instructions. The term "computer-readable medium" shall also include any medium that is capable of storing, encoding or carrying a set of instructions for execution by a processor or that cause a computer system to perform any one or more of the methods or operations disclosed herein.

In a particular non-limiting, exemplary embodiment, the computer-readable medium can include a solid-state memory such as a memory card or other package that houses one or more non-volatile read-only memories. Further, the computer-readable medium can be a random access memory or other volatile re-writable memory. Additionally, the computer-readable medium can include a magneto-optical or optical medium, such as a disk or tapes or other storage device to capture carrier wave signals such as a signal communicated over a transmission medium. A digital file attachment to an e-mail or other self-contained information archive or set of archives may be considered a distribution medium that is equivalent to a tangible storage medium. Accordingly, the disclosure is considered to include any one or more of a computer-readable medium or a distribution medium and other equivalents and successor media, in which data or instructions may be stored.

Although the present specification describes components and functions that may be implemented in particular embodiments with reference to particular standards and protocols, the disclosed embodiments are not limited to such standards and protocols. For example, standards for Internet and other packet switched network transmission (e.g., TCP/IP, UDP/IP, HTML, HTTP) represent examples of the state of the art. Such standards are periodically superseded by faster or more efficient equivalents having essentially the same functions. Accordingly, replacement standards and protocols having the same or similar functions as those disclosed herein are considered equivalents thereof.

The illustrations of the embodiments described herein are intended to provide a general understanding of the structure of the various embodiments. The illustrations are not intended to serve as a complete description of all of the elements and features of apparatus and systems that utilize the structures or methods described herein. Many other embodiments may be apparent to those of skill in the art upon reviewing the disclosure. Other embodiments may be utilized and derived from the disclosure, such that structural and logical substitutions and changes may be made without departing from the scope of the disclosure. Additionally, the illustrations are merely representational and may not be drawn to scale. Certain proportions within the illustrations may be exaggerated, while other proportions may be reduced. Accordingly, the disclosure and the figures are to be regarded as illustrative rather than restrictive.

One or more embodiments of the disclosure may be referred to herein, individually and/or collectively, by the term "invention" merely for convenience and without intending to voluntarily limit the scope of this application to any particular invention or inventive concept. Moreover, although specific embodiments have been illustrated and described herein, it should be appreciated that any subsequent arrangement designed to achieve the same or similar purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all subsequent adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the description.

The Abstract of the Disclosure is provided to comply with 37 C.F.R. §1.72(b) and is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, various features may be grouped together or described in a single embodiment for the purpose of streamlining the disclosure. This disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter may be directed to less than all of the features of any of the disclosed embodiments. Thus, the following claims are incorporated into the Detailed Description, with each claim standing on its own as defining separately claimed subject matter.

The above-disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments which fall within the true spirit and scope of the present invention. Thus, to the maximum extent allowed by law, the scope of the present invention is to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

What is claimed is:

1. A method comprising:

receiving first data from an internet protocol television system at a performance server, wherein the first data is associated with requests received by a video server for retransmission of particular multicast video data packets, wherein the first data denotes a trend based on performance data associated with the particular multicast video data packets, and wherein the first data indicates a potential network failure;

in response to the first data, querying, with a processor of the performance server, a plurality of network devices to receive performance metrics corresponding to multicast video data packets, wherein the network devices are multicast branching points between the video server and a multicast destination;

comparing, with the processor, the performance metrics to a performance metric signature to identify an action to inhibit the potential network failure; and

initiating the action from the performance server.

2. The method of claim **1**, further comprising determining a threshold event corresponding to receiving video data packets at the multicast destination, wherein the threshold event corresponds to a number of the multicast video data packets that are not received at the multicast destination or corresponds to a number of failed packet recovery requests.

3. The method of claim **1**, wherein the first data includes warnings, wherein a warning of the warnings indicates the trend associated with the multicast video data packets, wherein a first warning of the warnings indicates a first prediction that a rate of loss of the multicast video data packets is predicted to exceed a first threshold, and wherein a second warning of the warnings indicates a second prediction that a number of failed packet recovery requests is predicted to exceed a second threshold.

4. The method of claim **1**, wherein the first data includes data from a first network device that does not include a switch or router.

5. The method of claim **1**, wherein the performance metrics include a traffic metric associated with the multicast video data packets, a dropped packet metric, and a packet error metric.

6. The method of claim 1, wherein the multicast branching points include a switch, a hub, a gateway, a server, another network device capable of functioning as a branching point for multicast packet traffic, or combinations thereof.

7. The method of claim 1, wherein initiating the action includes sending a notice to a system administrator, redirecting network traffic, or both.

8. The method of claim 1, further comprising sending instructions to each network device of the plurality of network devices to substantially simultaneously record particular data associated with the performance metrics during a specified time interval.

9. The method of claim 1, further comprising:

receiving second performance data from a network device of the plurality of network devices, the second performance data corresponding to a time period prior to a delivery failure; and

generating a signature associated with the delivery failure based at least partially on the second performance data.

10. The method of claim 9, further comprising:

sending signature data corresponding to the signature to a network device of the plurality of network devices.

11. The method of claim 1, further comprising receiving the performance metric signature from a storage device coupled to the processor of the performance server.

12. The method of claim 1, wherein comparing the performance metrics to the performance metric signatures comprises:

receiving particular performance data corresponding to the performance metric;

identifying the performance metric signature, wherein the performance metric signature includes a threshold value;

comparing the particular performance data to the performance metric signature; and

when the particular performance data satisfies the threshold value, identifying the action as a particular action indicated by the performance metric signature.

13. A method comprising:

receiving first data from an internet protocol television system at a performance server, wherein the first data indicates a potential network failure and is associated with a number of multicast video data packets not received at a multicast destination, wherein the first data denotes a trend based on performance data associated with the multicast video data packets, and wherein the multicast video data packets are from a video server;

in response to the first data, querying, with a processor of the performance server, a plurality of network devices to receive performance metrics corresponding to the multicast video data packets, wherein the network devices are multicast branching points between the video server and the multicast destination;

identifying a delivery failure based on the performance metrics; and

initiating a response to the delivery failure.

14. The method of claim 13, further comprising receiving particular performance data corresponding to a time period prior to the delivery failure from network devices of the plurality of network devices in response to querying the plurality of network devices, the particular performance data indicating a first number of packets discarded due to errors.

15. The method of claim 14, further comprising performing pattern matching to compare the particular performance data to a signature representing a trouble pattern associated with the delivery failure.

16. The method of claim 13, further comprising receiving particular performance data corresponding to a time period prior to the delivery failure from network devices of the plurality of network devices in response to querying the plurality of network devices, the particular performance data indicating a first number of packets discarded due to network congestion.

17. The method of claim 16, further comprising performing pattern matching to compare the particular performance data to a signature representing a trouble pattern associated with the delivery failure.

18. The method of claim 13, wherein the performance metrics include a traffic metric associated with the multicast video data packets, a dropped packet metric, and a packet error metric.

19. A system comprising:

a processor;

a network interface accessible to the processor; and

a memory accessible to the processor, the memory having instructions that, when executed by the processor, cause the processor to perform operations including:

receiving first data from an internet protocol television system, wherein the first data indicates a potential network failure and is associated with a number of multicast video data packets not received at a multicast destination, wherein the first data denotes a trend based on performance data associated with the multicast video data packets, and wherein the multicast video data packets are from a video server;

in response to the first data, querying a plurality of network devices to receive performance metrics corresponding to the multicast video data packets, wherein the network devices are multicast branching points between the video server and the multicast destination;

identifying a delivery failure based on the performance metrics; and

initiating a response to the delivery failure.

20. The system of claim 19, wherein the operations further include receiving particular performance data corresponding to a time period prior to the delivery failure from network devices of the plurality of network devices in response to querying the plurality of network devices, the particular performance data indicating a first number of packets discarded due to errors and a second number of packets discarded due to network congestion.

21. The system of claim 20, wherein the operations further include causing the processor to perform pattern matching to compare the particular performance data to a signature representing a trouble pattern associated with the delivery failure, and wherein the signature is maintained at a storage device of an internet protocol television system that maintains signature data.

22. The system of claim 21, wherein the operations further include causing the processor to update the signature based on the particular performance data.

23. The system of claim 21, wherein the signature data maintained at the storage device is configured to represent a video trouble pattern, to identify a video delivery problem, or to identify a potential video delivery problem.

24. A server comprising:

a processor; and

a memory accessible to the processor, the memory having instructions that, when executed by the processor, cause the processor to perform operations including:

receiving first data from an internet protocol television system, wherein the first data is associated with

requests received by a video server for retransmission of particular multicast video data packets, wherein the first data denotes a trend based on performance data associated with the particular multicast video data packets, and wherein the first data indicates a potential network failure;

in response to the first data, querying a plurality of network devices to receive performance metrics corresponding to multicast video data packets wherein the network devices are multicasting branching points between the video server and a multicast destination;

comparing the performance metrics to a performance metric signature to identify an action to inhibit the potential network failure; and

initiating the action.

25. The server of claim **24**, wherein the first data includes warnings, wherein a warning of the warnings indicates the trend associated with the multicast video data packets.

26. The server of claim **25**, wherein the warnings include a first warning that indicates a first prediction that a rate of packet loss is predicted to exceed a first threshold and a second warning that indicates a second prediction that a number of failed packet recovery requests is predicted to exceed a second threshold.

27. A computer readable storage device having computer readable instructions stored thereon, when executed by a processor, cause the processor to perform operations including:

receiving first data from an internet protocol television system, wherein the first data is associated with requests received by a video server for retransmission of particular multicast video data packets, wherein the first data denotes a trend based on performance data associated with the particular multicast video data packets, and wherein the first data indicates a potential network failure;

in response to the first data, querying a plurality of network devices to receive performance metrics corresponding to multicast video data packets wherein the network devices are multicasting branching points between the video server and a multicast destination;

comparing the performance metrics to performance metric signatures to identify an action to inhibit the potential network failure; and

initiating the action.

28. The computer readable storage device of claim **27**, wherein initiating the action includes sending a notice to a system administrator, redirecting network traffic, or both.

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